ECON INCORPORATED

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A STUDY OF THE BENEFITS AND COST-EFFECTIVENESS OF SATELLITE-AIDED COMMUNICATIONS FOR EMERGENCY MEDICAL SERVICES, FIGHTING FOREST FIRES AND PICKUP AND DELIVERY TRUCKING APPLICATIONS

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FINAL

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Task VIII

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NOTE OF TRANSMITTAL

This study of the benefits and costs of improved communication services involving the use of mobile or transportable communication terminals was performed by ECON, Inc. for the Office of Space and Terrestrial Applications, National Aeronautics and Space Administration. The study was performed as Task VIII of Contract NASW-3047, and encompassed the estimates of the cost effectiveness and benefits of satellite-aided communications for emergency medical services, fighting forest fires and interstate pickup and delivery trucking. The field research and analysis for this study was performed during the period of June, July and August 1978, the cost-effectiveness analysis was performed during October and November 1978, and the final report was written during the period of November 1978 through April 1979.

Many members of the ECON staff contributed to this study. The study of emergency medical applications was performed by Ms. Celia Drumheller. Mr. Peter Stevenson performed the studies of the uses of improved communications in fighting forest fires and trucking. Mr. Michael Leeds, Ms. Marcia Rabinowitz and Ms. Nadia Zalokar assisted in the research for these studies. The quantitative methodology used was developed by Mr. Joel Greenberg and the studies were managed by Mr. B. P. Miller. The final report was authored by Ms. Celia Drumheller, Mr. Joel Greenberg, Mr. B. P. Miller and Mr. Peter Stevenson. The NASA Technical managers for this study were Mr. George Knouse of NASA Headquarters and Mr. Ahmed Meer of the Goddard Space Flight Center.

B. P. Miller
Vice President

TABLE OF CONTENTS

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES

LIST OF FIGURES
(Continued)

LIST OF TABLES

LIST OF TABLES
(Continued)

LIST OF TABLES
(Continued)

1. INTRODUCTION AND SUMMARY OF RESULTS

Commercial satellite-aided communication systems provide a fast and reliable worldwide communication link. Most present-day communication via satellite is handled by common carriers that integrate their space communications into their existing ground networks. The satellite provides a long-distance link; local and regional services are handled over ground links. Since a heavier payload necessarily increases the cost of the launch, the carriers have taken the economic advantage of using simple, relatively lightweight satellites, and placing the heavy technical burden on a few large and expensive regional ground stations.*

Such a communication system efficiently serves the easily accessible, heavily-populated areas of the world. There are, however, many remote, less densely populated areas for which terrestrial communication links are either physically impossible or economically prohibitive.** In these regions, a versatile, relatively inexpensive communication system could possibly improve the quality of public safety, health and commercial services.

A system that could respond to these needs would necessarily provide continuous 24-hour communication between any two points in a given area with both fixed and moving terminals. These communications include two-way video service between the stationary terminals and two-way audio service between the mobile or transportable terminals. The system would include small, affordable stationary terminals to serve health, education and other public services provided

*"Worldwide Space Activities," report prepared for the Subcommittee on Space Science and Applications of the Committee on Science and Technology, U.S. House of Representatives, September 1977.

**In the United States alone, it has been estimated that to reach the last 10 percent of the people would cost as much as reaching the first 90 percent. Remarks of Casper Weinberger, a News Conference on Applications Technology Satellite-F, May 22, 1974, p. 6.

by federal, state and local government agencies, as well as certain commercial services; portable terminals for emergencies and disasters; and mobile terminals to serve moving vehicles for emergency medicine, safety and law enforcement needs. This system requires that the burden of the satellite communications network complexity be transferred from the earth station to the satellite. This is accomplished by increasing the satellite transmission power, as well as its ability to focus this power. Thus, unlike conventional satellites that transmit moderately powerful broadcasts over large geographical areas, this communications satellite service would deliver high-power transmission to relatively limited areas. Multiple beams, each with relatively high power, would be required to provide comprehensive coverage. On-board switching is also necessary to provide the interbeam connectivity. The resultant decrease in the cost and the complexity of the terrestrial receiver stations could place satellite communications within the budgetary grasp of the small, independent user and could possibly open the door to a wide variety of social and commercial service communications by satellite.

The capability to provide communication services involving mobile and transportable earth stations has been demonstrated by the NASA Applications Technology Satellites and by the joint Canadian/United States Communications Technology Satellite.

The study reported here entails an investigation of the benefits and costs of improved communication systems for a selected set of land-based operations involving the use of mobile or transportable communication terminals. The specific operations studied are the use of telecommunications in emergency medical services, fighting forest fires, and interstate pickup and delivery trucking.

This study has three objectives. The first is to estimate the economic and social benefits of improved communications in each of the three applications.

Unless otherwise indicated in this report, the benefits are not dependent upon specific technologies or system configurations, but are rather the benefits of improved communication. The second objective is to estimate the cost effectiveness of satellite-aided communication systems in comparison with alternative terrestrial communication systems that can provide essentially the same capability. According to the generally accepted rules of benefit/cost analysis, if the present value of the benefits of a project exceed the present value of the costs, the project is worthy of investment.* Moreover, in a rational world, if one system is more cost effective than another for a given mission, it is likely that the cost-effective system will be chosen for development. Thus, if improved communication is beneficial, and satellite-aided communication is cost effective (relative to alternatives), it follows that satellite-aided communication should be developed. The third objective of this study is to estimate the market for improved communication services in the three applications. This third objective is accomplished by estimating the number and types of communication equipment and the communications traffic required for each cost-effective application. The succeeding sections provide specific quantitative data for each of the three objectives and for each of the three applications of improved communication.

The study of emergency medical services is an extension of a preliminary case study, performed by ECON during 1977. This study indicated that the potential exists for significant economic and social benefits through the use of

*Anderson, Lee G. and Russell F. Settle, Benefit-Cost Analysis: A Practical Guide, Lexington Books. While this criteria is often a necessary condition for the implementation of a project in the public sector, it is not by itself a sufficient condition, particularly when the question of private sector implementation is considered. In the case of private sector implementation, if the entity that implements the project cannot obtain the benefits through a pricing mechanism, some other form of compensation must be found if the investment is to be made attractive to the private sector.

improved communication in this application.* The forest fire and trucking applications are essentially new areas of study, although ECON earlier completed a preliminary (and low level of effort) study of the potential economic benefits of improved communications in the fighting of forest fires for the State of California Satellite Project.**

As specified by the Statement of Work for this study, five subtasks were completed for each of the three applications studied:

1. A specific user sample was selected for each application.

2. Case studies of the selected user samples were performed to establish a detailed understanding of user requirements, current methods and costs of operation. The methods of operation and cost data were determined through on-site visits to the users. An important part of this subtask was the collection of data used in establishing the costs of terrestrial systems now being planned or installed to provide services similar to those considered in the case studies.

3. Operational scenarios were developed for the delivery of the services identified in the case studies via a communications satellite. The costs of the systems to provide these services were to be furnished by NASA GSFC.

4. The size of the potential market was estimated for each case study in terms of the traffic and number of satellite terminals, and the costs in each case for both terrestrial and satellite-aided communications services.

5. The benefits of improved communications and the cost effectiveness of alternative systems were evaluated for each of the three applications.

Upon the completion of Subtask 3, it was determined that the cost estimates for the satellite systems that were to be furnished by NASA would not be available during this study. Since a methodology to estimate the costs of improved terrestrial communications services had been developed by ECON, in the absence

*"Preliminary Benefits Study for a Public Service Communications Satellite System," Task Order No. II, Final Report, ECON, Inc., Contract No. NASW-3047, October 16, 1978.

**California Satellite Cost-Benefit Assessment, Final Report, prepared for the State of California, State and Consumer Services Agency, ECON, Inc., April 12, 1978.

of estimates of the costs of satellite-aided services, a methodology was developed to estimate the benefits and cost effectiveness of satellite-aided systems as a parametric function of the important user cost parameters. The parameters deemed to be most important are (1) the cost of a user terminal, (2) the cost per minute for satellite connectivity, (3) the radius of coverage and (4) the expected life of the terrestrial equipment. The benefits and the cost effectiveness of satellite-aided communications were then developed and provided as a function of these parameters.

Satellite-aided emergency medical services is a particularly intriguing application because of the potentially dramatic impact that improved emergency medical services could have on the mortality rate from trauma in the nonmetropolitan United States. This study involved the analysis of emergency medical services systems now in operation in Mississippi, Texas and West Virginia. These existing systems use terrestrial communications networks to provide voice and data communications between the hospital and paramedics, who can then provide emergency services to the patient under the direction of a physician. For each of the regions studied, data was obtained on the number and distribution of emergencies by trauma type, and on the communications traffic associated with these emergencies. From the participating physicians, estimates were obtained on the reduction in mortality rates for each trauma type attributable to voice and data communications between the paramedic and the physician. Using data on population density and terrain type by state as the basis for generalization to the nonmetropolitan regions of the United States, it is concluded that about 59,000 lives per year could be saved with an emergency medical communication system that covers the entire nonmetropolitan United States. Using conservative estimates for the values of the lives saved, and omitting further benefits that might be possible through reductions in morbidity as a result of better emergency medical attention, the economic benefit of this reduction in mortality is estimated to be approximately $2 billion per year. The question of the cost effectiveness of satellite-aided systems to provide these services is a function of the designs of the competing terrestrial and satellite systems. Since the satellite system to provide these services has not been designed, it was necessary to analyze cost effectiveness in a parametric fashion. Using existing terrestrial systems as a reference point for comparison, satellite-aided emergency medical communication is shown to be cost effective for all combinations of connectivity charges up to $5 per minute and terminal costs up to $50,000 per unit.

For fighting forest fires, the benefits of satellite-aided communications are found to be in the range of $12 to $27 million per year. Satellite-aided communications are found to be cost effective for fighting forest fires for unit-terminal costs up to about $10,000 and for connectivity costs up to $0.15 per minute. The results of the pickup and delivery trucking study indicate that the satellite-aided communications system is not cost effective when compared to a terrestrial system that is capable of providing the same services.

Both technical and policy issues are involved in the implementation of satellite-aided communication in support of emergency medical services and forest fire fighting. For example, although NASA has demonstrated the capability to communicate with both moving vehicles and small portable terminals especially deisgned for medical use, the in-orbit switching capability needed to serve many users simultaneously has not been developed and the frequencies for this type of service have not been assigned. In addition to the technology, market aggregation is also a major issue. As opposed to the relatively monolithic trunking communications market, the emergency medical services communications market is quite diffuse. Emergency medical service districts are organized at the county level and there may be many such districts in a given state. Moreover, since it is not possible to establish a consumption-related pricing mechanism, the funding for emergency medical services is obtained from general taxation as opposed to user fees. This moves the decision to implement these systems from the market to the political and policy arena. The President recognized these issues in his space policy announcement and directed the National Telecommunications and Information Administration to assist in market aggregation, technology transfer and possible development of public satellite services in areas, such as health services, that receive little attention from commercial satellite operations.*

It is hoped that the potential benefits and cost effectiveness of satellite-aided emergency medical services described in this report will support the efforts of NASA and other federal and state agencies to continue the development and demonstration of this important application.

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*"The White House Fact Sheet--U.S. Civil Space Policy," October 11, 1978.

2. OVERVIEW OF BENEFIT/COST METHODOLOGY

The objective of the analyses presented in the following sections of this report is to establish an estimate of the net benefits (benefits less costs) that might result from the use of satellite-aided communication in emergency medical services, forest fire fighting and trucking applications. The establishment of net benefits, in the broad sense, imlplies the establishment of (1) the present value of the incremental benefit stream that might result from the use of the satellite-aided communications technology in these application and (2) the present value of the incremental cost stream that might be incurred to achieve the incremental benefit stream. The establishment of incremental benefits and costs requires the determination of the benefit and cost streams that would result with and without the development and use of the satellite technology. This, in turn, requires consideration of both nonrecurring and recurring costs as seen by both the public and private sectors. In particular, the nonrecurring costs of a NASA research and development program must be considered together with both the time-phased costs incurred by both the public and private sectors that enable them to use the satellite-aided communication systems and the time-phased costs associated with the use of the satellite systems. The benefit stream can then be developed with the appropriate time relationship to the costs. A similar analysis must be done of benefits and costs for communication systems based on the use of other technologies.

Typical benefit, B, and cost, C, streams are illustrated in Figure 2.1. Two scenarios are illustrated: one, associated with the use of satellite-aided communications technology (denoted by a subscript "s") and one associated with terrestrial

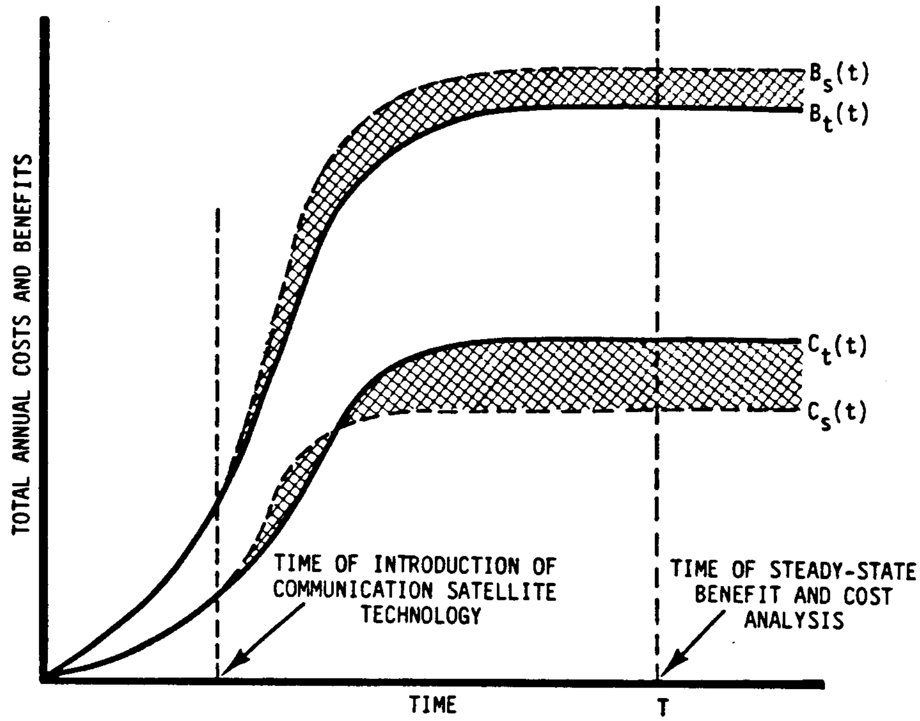


FIGURE 2.1 BENEFITS AND COSTS AS A FUNCTION OF TIME FOR SPECIFIED LEVELS OF CAPABILITY

(radio telephone, UHF radio and VHF radio) technologies (denoted by a subscript "t"). Since the required satellite-aided technology will not be available until sometime in the future, a number of potential communication system users will decide in the interim to use the terrestrial technology to satisfy their needs. When the required satellite technology becomes available, two paths are possible: (1) the path denoted as B_s and C_s and (2) the path denoted as B_t and C_t (each scenario has a B and C path). The user costs and benefits, but not the NASA research and development costs, are illustrated. It is assumed that the use of satellite-aided technology will reduce costs. It is possible that reduced costs will, in general, lead to an increased rate of user acceptance--thus, it is possible that the C_s curve will initially be above the C_t curve. An increase in user acceptance rates will lead to a speed-up of benefits. Lower user costs may also lead to an increase in the number of users who will employ communication systems--hence, a possibility that, for equal capability systems, B_t may exceed B_s in the long term. If the satellite-aided systems offer additional capability beyond that possible with terrestrial systems (for example, see the timeliness benefits of satellite-aided systems asssociated with the forest fire applications in Section 4.2), then it is likely that B_s will be greater than B_t. Thus, the net benefits of developing and using satellite-aided communications technology is given by the present value, NPVB, of the difference in the benefit streams plus the present value of the difference in the cost streams less the present value of the cost of the research and development program. This may be expressed as:

$$NB(t) = B_s(t) - B_t(t) + C_t(t) - C_s(t)$$

$$NPVB = \sum_t \frac{NB(t)}{(1+r)^t} .$$

This is illustrated as the cross-hatched area in Figure 2.1. In general, user decisions made prior to the availability of the required satellite-aided technology and operational systems detract from the number of potential users for the communications satellite services and, hence, reduce the net benefits that may result from the development and use of communications satellites. However, the specific time of availability of the required satellite-aided technology is not known. Also, in the long term, these same users will again enter the marketplace and, if the satellite-aided technology is cost effective, the communications satellite will be purchased.

The development of the net benefits, in the broad sense, requires the development of the with and without scenarios as a function of time and implies an analysis of both the possible time at which the satellite-aided technology will become available and the rate of penetration into the marketplace of the terrestrial and the communications satellite-aided technologies. Since both of these required analyses that were well beyond the scope of the reported effort, the net benefits are established in a somewhat restricted sense. The net benefits are established as the average steady-state annual benefit, $\bar{B}$, that may accrue at some distant point in the future; that is,

$$\bar{B} = B_s(t=T) - B_t(t=T) + C_t(t=T) - C_s(t=T) .$$

When considering systems having equal capabilities, that is, $B_s(t=T) = B_t(t=T)$, the benefits are the result of achieving the level of capability and are independent of the specific technology employed. In this situation, the concept of cost effectiveness is important. The measure of cost effectiveness is the difference in the cost of terrestrial systems and satellite-aided systems that are required to achieve the same level of capability. That is, the cost effectiveness, CE, of satellite-aided systems relative to terrestrial systems is given by

$$CE = C_t(t=T) - C_s(t=T) .$$

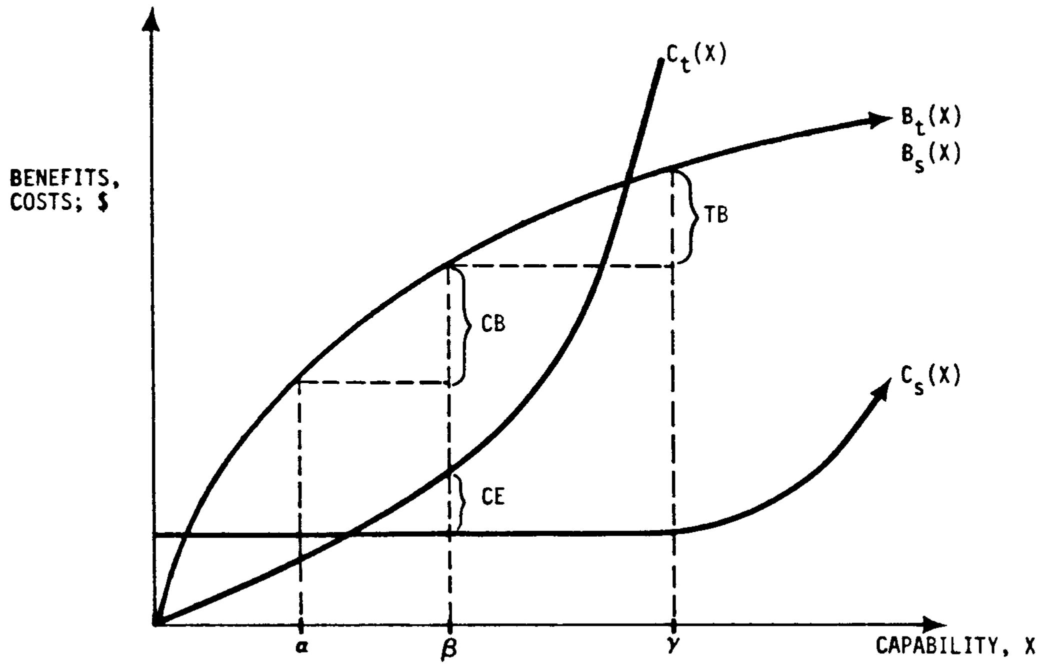
In the emergency medical service application, it was found that both the terrestrial and the satellite-aided systems could achieve the required capability. Therefore, it is important to establish the magnitude of the benefits of improved communications services that may be provided by either system. These benefits are a measure, then, of the value of improved communication. The value of one system versus another is indicated by the magnitude of the CE measure.

In the forest fire application, it was found that the satellite-aided systems offered a capability (i.e., timeliness) that could be provided by terrestrial communication systems only at an unrealistically high cost. It was found that timeliness (i.e., the time interval required to establish the communication links) affected benefits: Benefits were inversely related to the time interval required to establish the communication link. Therefore, the value of the satellite-aided technology is not adequately reflected by establishing the cost-effective measure--increased capability benefits need also be considered. A similar situation was found existing for the trucking application. When the terrestrial system has gaps in its coverage, the satellite-aided technology offers the ability to eliminate these gaps with a resulting increase in trucking productivity. Thus, in general, both cost savings and other benefits resulting from increased capability must be considered.

In order to develop realistic models for establishing benefits and costs, case studies were undertaken in each of the application areas. Three case study areas were analyzed for the emergency medical service application, two fires were analyzed for the forest fire application and five firms were analyzed to represent the trucking industry. The objective of the case studies was to establish a detailed understanding of the overall application area by developing a detailed knowledge of several specific cases (for example, for the emergency medical service application, case studies were conducted in the Hattiesburg area of Mississippi, in central Texas outside and primarily west of Fort Worth, and in an area in north central West Virginia that includes the cities of Fairmont, Clarksburg and Morgantown). A further objective of the case studies was to collect sufficient detailed data (cost- and traffic-related) so that the specific case study result could be scaled across the total application area. The scaling was done by using the specific case study areas as proxies for the remainder of the application areas. This meant that the results of three emergency medical service case studies were scaled to include the total nonmetropolitan United States (50 states) and included the benefits and costs associated with cardiac arrhythmia, poisoning, burns, emphysema trauma, and shock and head and spinal injuries associated with auto accidents. The results were limited to those types of traumas, as data for other types was not available in the case study areas. Scaling was in accordance with the terrain type, population density and existing medical services. The two forest fire case studies were scaled to include all large forest fires. The five trucking case studies were scaled across all pickup and delivery trucking firms.

For the emergency medical service applications, the benefits from improved communications are the result of mortality rate reduction and cost savings. The mortality rate reduction benefits are measured in terms of the human capital value of lives saved as a direct result of the improved communications. It was originally intended to also consider the impact of improved communication on morbidity; however, it was not possible to estimate the morbidity reductions and cost savings as the data necessary to analyze morbidity is not currently available from the emergency medical districts. The cost of terrestrial systems is established as a function of terrain type, radio range and the portion of the fixed equipment charged to the emergency medical service application. The equipment costs are based primarily upon supplier data. The satellite-aided system costs are the sum of ground terminal annual cost and connectivity (per use) cost. Since the satellite-system ground terminal and connectivity costs were not known, they were treated parametrically, and the cost-savings benefits were established in terms of the ground terminal costs and connectivity costs.

For the forest fire fighting application (refer to Figure 2.2), the benefits of satellite-aided technology resulted from (1) reducing the time required to establish communication after the outbreak of a large fire, TB, (2) from providing additional required capacity, CB, and (3) from the cost savings relative to terrestrial communication systems, CE. The capacity benefits were not considered when comparing the satellite-aided system with improved terrestrial systems. The timeliness benefits are the result of improving the efficiency of handling the forest



X	=	LEVEL OF CAPABILITY
$B_t(X)$	=	BENEFITS FROM A COMMUNICATION SYSTEM BASED UPON TERRESTRIAL TECHNOLOGY WITH CAPABILITY X
$B_s(X)$	=	BENEFITS FROM A COMMUNICATION SYSTEM BASED UPON SATELLITE-AIDED TECHNOLOGY WITH CAPABILITY X
$C_t(X)$	=	COST OF A COMMUNICATION SYSTEM BASED UPON TERRESTRIAL TECHNOLOGY WITH CAPABILITY X
$C_s(X)$	=	COST OF A COMMUNICATION SYSTEM BASED UPON SATELLITE-AIDED TECHNOLOGY WITH CAPABILITY X
α	=	PRESENT TERRESTRIAL SYSTEM LEVEL OF CAPABILITY
β	=	PRESENT LEVEL OF CAPABILITY PLUS ADDED CAPACITY CAPABILITY
γ	=	PRESENT LEVEL OF CAPABILITY PLUS ADDED CAPACITY AND IMPROVED TIMELINESS CAPACITY
CB	=	CAPACITY BENEFITS
CE	=	COSI EFFECTIVENESS
TB	=	TIMELINESS BENEFITS

FIGURE 2.2 BENEFITS AND COSTS IN TERMS OF CAPABILITY (FOREST FIRE APPLICATIONS)

fire fighting logistics and of reducing the over-ordering that normally takes place during the first few days of the fire. The cost savings are the result of differences in the annualized capital costs and the costs required to establish and provide communications. The satellite-system ground terminal and connectivity costs also were treated parametrically, and the cost effectiveness established in terms of these variables. It should be noted that since total benefits consist of added capability benefits and cost effectiveness benefits (i.e., TB + CE), satellite-aided systems may be preferable to terrestrial systems, even though they may not be cost effective (i.e., the added capability benefits exceed cost-effectiveness benefits).

For the trucking applicatin, the benefits of satellite-aided technology resulted from increasing the labor productivity due to the reduction in radio-coverage dead spots and from cost savings relative to terrestrial communication systems. Thus, both added capability and cost-effectiveness benefits were considered, the same as for the forest fire applications. However, since the added capability (i.e., elimination of dead spots) benefits might also be achieved by improved terrestrial systems, the benefits of the satellite-aided technology were derived relative to current terrestrial systems (i.e., added capability benefits plus cost-effectiveness benefits) as well as improved terrestrial systems (i.e., cost-effectiveness benefits). Again, the satellite system ground terminal and connectivity costs are treated parametrically and the cost effectiveness is established in terms of these variables.

3. EMERGENCY MEDICAL APPLICATIONS

3.1 Introduction

In many areas of the United States, those which are largely rural or nonmetropolitan, adequate services of doctors, hospitals and even emergency medical services are not readily obtainable. As a result, these areas experience higher mortality and morbidity rates in certain health categories.

Because of the immediacy of the patient's need, emergency medical services (EMS) are among the most difficult to supply in the rural environment. Judging from mortality rates in automobile accidents and other such statistics, there is a need for vast improvement in rural EMS to make the level of service comparable to similar services in the more densely populated areas. The major problem in providing EMS to nonmetropolitan areas is that large geographic areas and low population densities make such services unprofitable. Historically, the EMS providers have sought either to combine services that could share equipment and facilities such as the combination of EMS and funeral services (with the obvious conflicts of interest) or have done with minimal EMS services. Today, however, advances in medical equipment and facilities are becoming available which both improve the quality of service and keep costs to a minimum. The use of paramedics and citizen education are examples of some recently implemented improvements. In the future, there may be even greater opportunities for cost-effective advances.

Communications is an essential part of effective EMS. The use of a satellite-aided system for EMS communication provides another possible opportunity to improve the quality of service and minimize or reduce the associated costs. One of the major expenses in conventional systems for EMS communication is the capital cost of terrestrial equipment. In a UHF or VHF radio system, repeater towers, antennas, etc., are required to relay the radio signal from an ambulance or portable unit to a hospital; in a system of radio telephones or hardwire, again, large investments in switching stations or other capital are required. For large areas of low population density, particularly if the terrain is rugged, these expenses increase. A satellite-aided mobile communication system would allow communications between the ambulance and the hospital without costly terrestrial equipment and could be extremely cost effective. If so, it would allow areas that could ordinarily not afford a conventional communication system to provide high-quality service, thus saving additional lives and reducing morbidity due to emergency situations.

The general role of the EMS provider is to attempt to stabilize the victim's condition and then transport him or her to an area of definitive care. Because paramedics and other medical technicians who staff emergency medical services have the first responsibility for saving the victim's life but are not fully trained as doctors, it is, in many cases, beneficial for the paramedic to be able to communicate with a doctor to establish proper diagnosis and thus the proper treatment. Communications in emergency medical services are aimed at:

1. Ensuring that the best decision on diagnosis and treatment is made
2. Providing the extension of techniques available to the paramedic by shifting the responsibility to the doctor
3. Coordinating the care facilities to ensure the speed and smoothness of progress through the emergency medical service system.

In order to make the proper diagnosis, two-way voice and telemetry of vital signs and EKGs are extremely important. In many states, if paramedics have a doctor's approval, they are allowed to practice a number of treatments that would otherwise not be allowed. This shifts the legal responsibility for the treatment from the paramedic to the doctor. This responsibility shift has been instrumental in allowing paramedics to practice defibrillation, fluid replacement and drug therapy, which have in turn been responsible for saving the lives of many victims. However, it is important to note that, without proper information on vital signs and perhaps an EKG reading, no doctor will prescribe these protocols; therefore an adequate advanced communication system is essential for establishing these treatments.

It is known that there is an inverse relationship between the time required to receive definitive care and patient mortality. The longer it takes a patient to receive first emergency and then definitive care, the less likely it is that he will survive. Because of this, two-way voice communication is essential in coordinating care facilities to assure the fastest progress through the system. Two-way voice communication can enable the receiving hospital to know exactly when the patient will be arriving, what the problems of the patient are, what treatment he has received and other such vital information. This saves valuable time when the patient reaches the emergency room. Voice communication can also allow the paramedics to establish communication with a resource hospital--perhaps not the nearest hospital, but a hospital that is advanced in the care of the type of trauma that has been encountered. In this way, a paramedic is able to get the most up-to-date advice on treatment.

Much of the time, since paramedics are able to stabilize a victim before transport, telemetry of vital signs and EKG during transport is not necessary. However, the capability for this type of transmission is important since many victims are not stabilized or develop complications during the transport. This is particularly true in areas where long transport distances are likely to be encountered.

Slow-scan video and high-speed video are not now in use for emergency medical services, and the doctors contacted for this study have no experience in the use of such equipment. However, they believe that the only benefit would be to assure the doctor of the condition of the patient at the scene in order for him to give the proper treatment advice. This benefit of assurance to the doctor and to the paramedic is not readily quantifiable. And while it is believed that video would be of some assistance, this benefit has not been calculated within this study. It was noted, however, by a number of doctors that if there was telemetry of excellent color quality in either slow-scan or high-speed video, much greater benefits could be expected.

Uses of telemetry in emergency medical services for various types of trauma are summarized in Table 3.1.

In a previous benefit study,* ECON looked at the benefits from satellite communications in the treatment of arrhythmia victims. Benefits were determined based on the experience of a case-sample area around Hattiesburg, Mississippi. These results were then generalized to the United States on the basis of population. In order to improve the quality of the estimates, this study has undertaken to select other case-study areas to provide generalization based on relevant statistical information for the United States and to provide the cost of communications using both satellite and alternative terrestrial techniques. In order to select appropriate user samples, the following criteria were used:

- Market aggregation potential
- Data availability

*"Preliminary Benefits Study for a Public Service Communications Satellite System," ECON, Inc., Report No. 77-263-4, 31 December 1977.

TABLE 3.1 THE USES OF TELEMETRY IN EMERGENCY MEDICAL SERVICES

TRAUMA TYPE	COMMUNICATION REQUIRED	APPLICATIONS(S)	LOCATION(S) REQUIRED
CARDIAC (ARRHYTHMIA)	2-WAY VOICE, EKG, VITAL SIGNS	DIAGNOSIS, PARAMEDIC PROTOCOL, EMERGENCY SERVICE, COORDINATION	PATIENT, VEHICLE
AUTO (SHOCK, BLEEDING, MAJOR CHEST TRAUMA, HEAD AND SPINAL)	2-WAY VOICE, EKG, VIDEO, VITAL SIGNS	DIAGNOSIS, PROTOCOL, ASSURANCE (VIDEO), COORDINATION	PATIENT, VEHICLE
POISONING	2-WAY VOICE, VITAL SIGNS	DIAGNOSIS, PROTOCOL, COORDINATION	PATIENT, VEHICLE
BURNS	2-WAY VOICE, VITAL SIGNS, VIDEO	DIAGNOSIS, PROTOCOL, ASSURANCE (VIDEO), COORDINATION	PATIENT, VEHICLE
MEDICAL (DIABETIC SHOCK, EMPHYSEMA, ETC.)	2-WAY VOICE, VITAL SIGNS	DIAGNOSIS, PROTOCOL, COORDINATION	PATIENT, VEHICLE
BEHAVIOR	2-WAY VOICE	COORDINATION	VEHICLE

- The magnitude of potential traffic
- The probability of early commercialization
- The feasibility of experimental verification.

By the use of the first of these criteria, market aggregation potential, it was hoped that a group of user samples could be selected that would be geographically, demographically, medically and economically representative of the United States as a whole. The use of such a set of sample sites would lead to an extrapolation to the United States that would provide an unbiased estimate of both the benefits and costs of satellite and other communication systems.

The second criterion for selection of the user sample was data availability. In order to perform this study, it was necessary to gather certain types of statistical information; it was desirable to find an area that had already collected and compiled these in a way that was organized and consistent with other sample selections. In addition to geographic and demographic information for each case-study area, additional information was needed on the existing communication systems, mortality and morbidity statistics for patients entering their EMS system as well as costs.

The magnitude of potential traffic was another important consideration in the selection of the sample sites, thus the need for communications was a function of the area size, the number of people within the area and the frequency of use of the EMS system. The probability of early commercialization was another interesting characteristic of possible sample sites. It is believed that satellite communications will be most beneficial relative to terrestrial systems in areas of low population density. In these areas, it is very expensive to build terrestrial systems that require radio towers to cover the entire area. Because of this, it is believed that nonmetropolitan areas would be the most likely areas for early commercialization of satellite-aided communication systems. In view of this, sample selection was primarily limited to nonmetropolitan areas and extrapolations to the rest of the United States were based entirely on nonmetropolitan areas within the United States. Other factors affecting the probability of early commercialization are the existing equipment, the expected life of that equipment, the expansion plans of the area and the perceived communications needs of the area.

The final criterion for selection of a sample site was the feasibility of experimental verification. This criterion addresses the characteristics of user interest and political or institutional constraints. If an area is not interested in improved communication systems in general or in satellite-aided communication systems in particular, experiments to verify the cost estimates and benefits of such a system in that area would be ill-advised. It is important to note here that, even in areas where experimental verification is very likely, not all benefit areas will be addressable. There are some empirically-measurable benefits, as well as other benefits, that are intangible. However, it is believed that where experimental verification problems of this type arise, they are not sample-site specific. After reviewing a large number of potential case study areas, three areas were chosen.

The first was the Hattiesburg area in southeastern Mississippi. This is the same area that was considered in the previous ECON study. The two new sites selected in this study are an area in central Texas, outside and primarily west of Fort Worth, and an area in north central West Virginia that includes the cities of Fairmont, Clarksburg and Morgantown. The locations within each state can be seen in Figures 3.1, 3.2 and 3.3.

The results obtained from the sample- or case-study areas are scaled to other geographic areas in the United States in order to obtain an estimate of the potential EMS benefits attributable to satellite-aided communications support. To

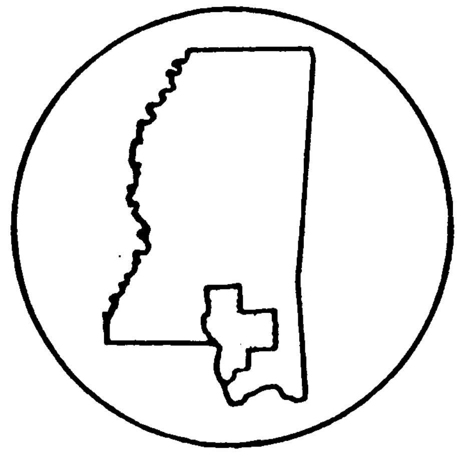


FIGURE 3.1 MISSISSIPPI AREA SELECTED FOR EMS STUDY

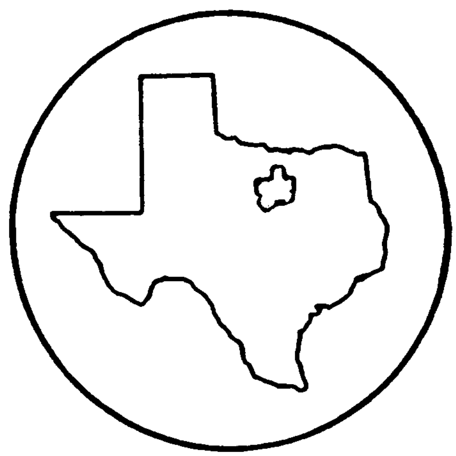


FIGURE 3.2 TEXAS AREA SELECTED FOR EMS STUDY

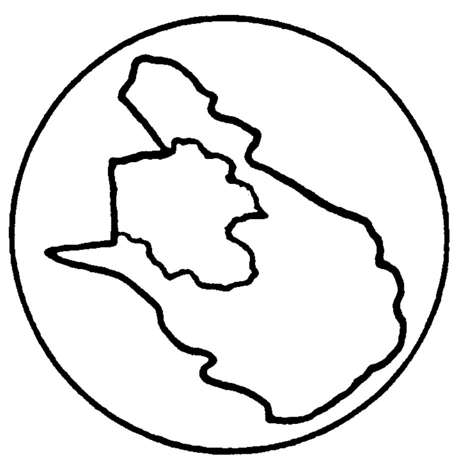


FIGURE 3.3 WEST VIRGINIA AREA SELECTED FOR EMS STUDY

accomplish the scaling, a number of characteristics of the sample areas must be considered. Population density obviously affects the likelihood of profitability for certain types of communication systems. As described previously, it is believed that, in large areas of low population density, it will be extremely expensive, relative to the potential benefits of EMS communication, to build terrestrial systems. Per capita income is likely to affect an area's ability to pay for a communication system--this, of course, assumes that local taxes will be used, at least in part, for emergency medical services. The age structure of the population is important, because it gives some insight into the types of problems encountered. For instance, if you have a pocket of population where the average age is considerably older than the national nonmetropolitan average, one would expect to find a higher incidence of heart disease and heart problems and perhaps a lower incidence of automobile or personal violence accidents. Such a population would bias the estimates of benefits. The number of square miles served by a hospital and the number of fully-equipped emergency medical rooms or services give some indication of the quality of medical service in the area. Geographic considerations affect the cost and, therefore, the likely selection of a communication system. In rugged terrain, terrestrial systems become more expensive because the range of each unit, tower or mobile becomes shorter. In order to get comprehensive coverage in these areas (that is, in order to be able to service the victim in a valley as well as the victim on a mountain top), necessary expenditures increase.

The likelihood of severe weather and other complicating factors are also likely to affect the type of communication system that an area selects. For instance, in the Mississippi site, when the choice of a UHF, public telephone or satellite system was discussed, it was found that a public telephone system would not be acceptable because of the number of hurricanes and the frequency with which the telephone system is knocked out.

The legal aspects of emergency care in an area are likely to affect the estimate of benefits. For instance, if in a particular state it is not legal under any circumstances for a paramedic to practice defibrillation or aggressive drug therapies, the benefits of communication with a doctor will be reduced. This also implies that if remote communication allows treatments that would not otherwise be possible, the benefits of those treatments will accrue to the communication system. The expected use of telemetry in an area and the expected improvement due to advanced communications are likely to vary with the experience of the persons involved with EMS in those technologies. One would expect that an area having more extensive experience with types of communications and the use of telemetry would provide better estimates of the benefits from those systems than would an area having little or no experience.

In making a survey to select sample areas, it was discovered that data availability was the limiting factor. Mortality and morbidity statistics seem particularly limited; in order to develop such statistics, patient follow-up studies must be undertaken. In other words, a patient who enters the emergency service must be traced through that service and through the hospital to determine the length of stay and condition on discharge. It is impossible to empirically measure the improvement in morbidity among emergency service patients; one must determine what happens to patients that travel through the system. These types of studies are extremely expensive because they involve large amounts of data collection and correlation. Experience has shown it to be less likely that these types of studies will have been completed in rural areas due to the depressed nature of emergency services in general. In addition, it was found that data collection before the existence of advanced communication systems was also quite rare. In many areas, federal grants from the U.S. Department of Health, Education and Welfare (DHEW) require that an evaluation program be carried out. However, most areas are just starting these programs, and data collection to date has been quite limited.

In addition to data that was simply not available, many types of data were found to be inconsistent. Very often, even the number of runs by type was inconsistent. This is particularly true in areas that have large numbers of independent providers, where providers did not report to a central office and therefore categorization of runs by type was left to the individual provider. For instance, if a patient was severely injuried in a automobile accident and developed shock, some reporting agencies would report that the patient was suffering from shock, others would report that he was suffering from an automobile-related accident, while still others would specify chest traumas, contusions, etc. Once this type of information has been recorded and the paramedic that was at the scene has moved on, inconsistencies are not verifiable. Because of this, there may be some slight inconsistencies in the data collected and, therefore, in benefit calculations from one area to another.

It is important to note here that morbidity statistics were not available in any of these areas. Because of this, benefits from reduced morbidity have not been included in this study.

In order to determine the data availability of particular sample areas in the United States, ECON performed an extensive literature search of relevant journals and publications. In addition, DHEW and the Department of Transportation (DOT), (at both national and regional levels and, in most cases, the state director's office of emergency medical services) were contacted in order to determine the most likely sample sites. Also, a large number of persons acting as communications consultants to individual areas were contacted. The overall state of data availability is summarized in Table 3.2.

In estimating the costs of various systems, the cost to build the entire system was analyzed with the EMS bearing either 100 percent or 50 percent of the stationary capital costs. This was done to account for possible cost sharing of the EMS communication system when it can also be used for other emergency or public safety communication purposes. No account was taken of the possible use of existing radio towers or the possible leasing of tower space in any particular area, because it is not known whether such towers will be available to any particular area or, in general, to how many areas across the United States. The use of existing towers will, therefore, lower the cost of both UHF and public telephone-type services. In one of the areas studied, existing towers are available; therefore, the costs of that system will be considerably lower than the estimate given.

It is also important to note that estimates reflect the cost to build the entire system, rather than the cost to add to the existing system to bring it to quality of service levels expected. Over the life of any system (which is assumed to be ten years), the whole system will be replaced. Therefore, capital cost is not expended in one year but, rather, more slowly over a period of time. New equipment acquisitions replace old equipment or expand the system to increase its capabilities.

Since there are severe problems with frequency allocations and the FCC strongly discourages the use of VHF radio (in fact, it does not issue new VHF permits), a VHF system has not been costed. In addition, the possibility of using microwave terrestrial systems has not been costed. This type of system is

TABLE 3.2 SOURCES AND STATE OF DATA AVAILABILITY	
AVAILABILITY	TYPICAL AREAS
• DATA DOES NOT EXIST OR IS INCONSISTENT	• VERMONT, MAINE, NEVADA
• DATA EXISTS BUT IS NOT COMPILED	• WYOMING, IOWA, NEBRASKA, UTAH
• DATA EXISTS FOR LARGELY METROPOLITAN AREAS	• SAN MATEO, CALIFORNIA AND CHICAGO, ILLINOIS
• DATA EXISTS FOR LARGELY NON-METROPOLITAN AREAS	• WEST VIRGINIA, TEXAS

relatively much more expensive and provides no additional benefits; therefore, it is believed that no EMS district would select the use of a microwave system.

Benefits have been provided in terms of number of lives a year saved and an evaluation of this based on the human capital approach which is explained in greater detail later. It is assumed that the benefits for a given level and quality of service are independent of the communication system type. Therefore, if two types of systems provide exactly the same level and the same quality of service, the benefits of those systems will be the same. Costs provided are the cost of steady-state operations; no research and development cost or other start-up costs other than capital equipment have been included.

To recapitulate, the limitations of running case studies are basically those of data availability and consistency; also, mortality statistics are extremely limited and morbidity statistics are not available, particularly for rural or nonmetropolitan areas. The cost estimates for alternative systems are also limited. In many areas of the United States, cost evaluations for systems other than the system in use have not been undertaken. In addition, very often the existing system in use was developed in a piece-meal fashion; therefore, costs were accrued by individual ambulance services or counties and are not recorded consistently or have not been compiled. Data was also found to be slightly inconsistent even in some of the areas where the system is operated by a central office. For example, in the West Virginia region, since the system was developed as a number of small independent systems and only later aggregated into a regional system, cost information was somewhat inconsistent.

Also discussed earlier was the inconsistency in the categorization of runs or problem type. However, these slight aberrations were not believed to be significant enough to cause problems in benefit evaluation. Another limitation of the study, in general, is that the effects of competition have not been considered. In other words, the possiblity of reduced costs of alternative terrestrial systems (either the public telephone or the UHF system before or at the time of the satellite system introduction) have not been considered. Since the satellite system is not operational at the moment, there may be considerable change in both the types of communications available terrestrially and the costs of those systems before such a system can be developed. In addition, as previously mentioned, the study does not consider the possible advantage of using existing towers.

3.2 Benefit Cost Methodology

The general methodology used in determining the benefits and costs associated with three communication systems will be discussed in this section. These systems are: (1) a UHF, radio telephone system, from now on referred to as the UHF system, (2) a system combining public telephone and radio telephones, also known as the Radio Telephone Switching System (RTSS), and (3) a satellite-borne radio repeater system, from now on called the satellite system. The first two types, collectively, are referred to as terrestrial systems. (See Figure 3.4 for a

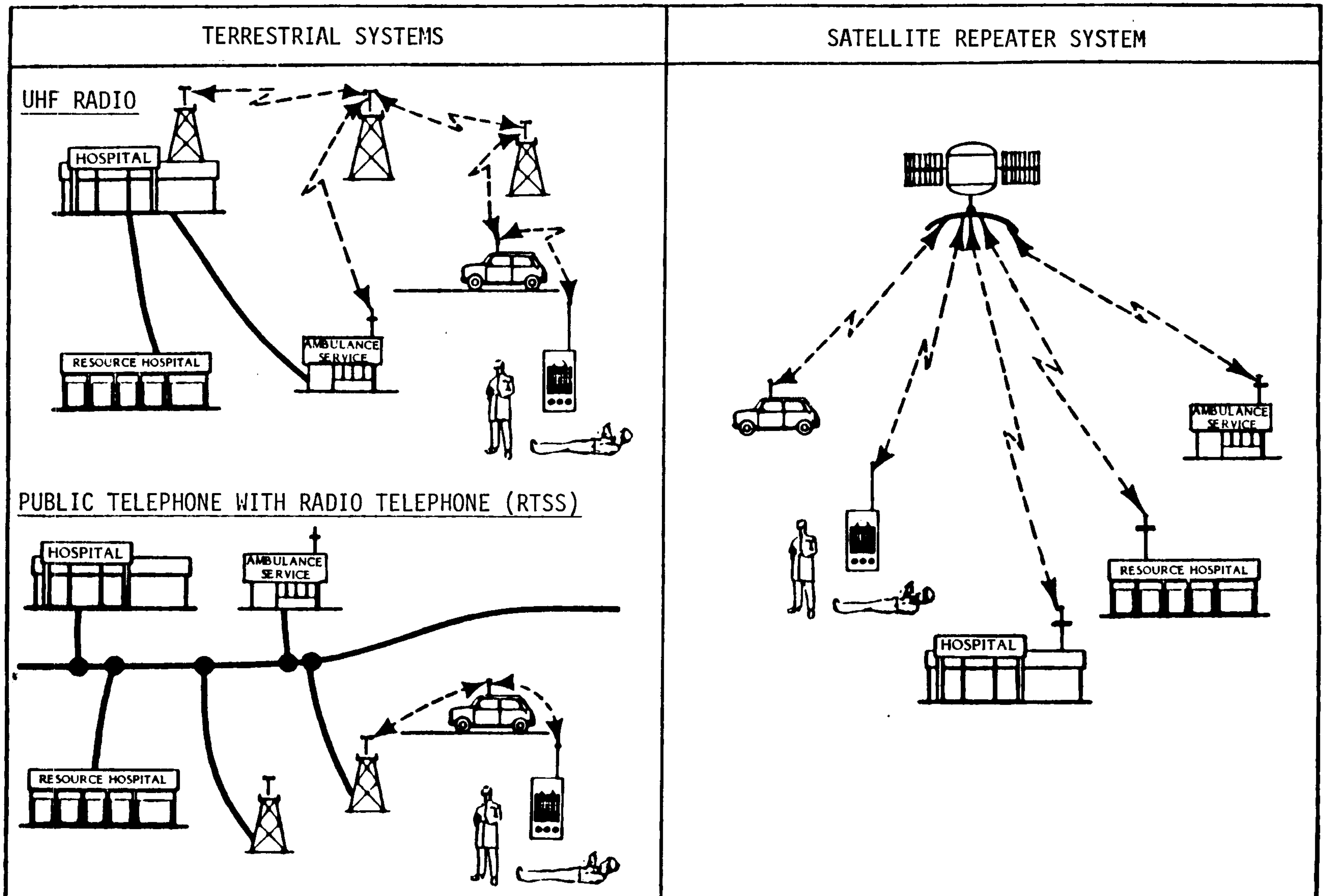


FIGURE 3.4 EMS SYSTEM MODELS

pictorial representation of each system.) VHF, microwave, devoted hardwire and hybrid systems have not been analyzed: The microwave and hardwire systems were felt to be unnecessarily expensive, and new VHF systems cannot now be licensed. Also, the examination of all the possible combinations of systems was beyond the scope of this study. The study has considered several types of benefits which will be described in the following discussions. In general, benefits fall into two categories: (1) independent benefits, including reduced mortality and morbidity and (2) system-dependent benefits, including cost effectiveness and differential capacity benefits.

3.2.1 Benefits of Advanced Communications

Since each of the three systems to be considered would provide essentially identical service, there are a number of benefits that would accrue whichever system was put into operation. The magnitude of these benefits for a particular area would be independent of the type of system selected. It is important to note, however, that the magnitude of these benefits that will be captured by a particular system will be dependent on the extent and quality of whatever communication system exists when the new system is installed. For example, if a satellite system is installed in a ten-county area (where all the counties are identical), when there is no existing service, the benefits of the satellite system would amount to X dollars. If, on the other hand, the system were installed in the same area but two of those counties already had a UHF system that could provide the same service (that would either stay or be replaced by the satellite system), the benefits would only be 0.8X dollars.

Benefits of this type; i.e., system independent, are generally social welfare benefits. Such benefits include reduced mortality and morbidity among patients using the EMS system. Due to the data limitations previously discussed, only the mortality benefits of advanced communications are addressed in this study. It is believed that morbidity and the resulting hospitalization, etc. would also be largely reduced by advanced communications in EMS. While data to perform such an analysis was not available for use during this study, it is noted that such data will be available within one or two years; it is currently being collected under DHEW grants.

Mortality benefits from advanced communications were estimated for the nonmetropolitan United States and for the following example trauma types:

Cardiac, Arrhythmia

Auto, Shock

Auto, Head and Spinal

Poisoning

Burns

Medical, Emphysema.

In estimating benefits, data and estimates were collected from each of the three case-study areas on the number of additional lives that could be saved with the use of an advanced communication network, given the number of emergency runs made for patients with a given trauma type. The number of lives that could be saved each year, by trauma type in the nonmetropolitan United States, was then estimated using national emergency run statistics and extrapolating the results from those case studies in which data was available on the specific trauma type. For instance, the cardiac arrhythmia results obtained are based on all the case studies, but the national emphysema results are based only on the Texas case study because data on emphysema victims was not available at either the Mississippi or the West Virginia site.

There is, at present, no universally accepted method of placing a dollar value on a human life. However, in response to the growing need for just such a measurement, a number of techniques have been developed. These techniques range from the use of insurance payments and court settlements to Acton's recent use of a survey in an "indirect" attempt to get individuals to reveal the value that they place on their own lives.* Unfortunately, we must reject the former technique as far too inconsistent a measure, and can consider the latter to be only an unproven possibility.

The methodology used in this report is that of measuring "human capital." The idea behind this approach is to measure the indirect losses in earnings that occur due to death or injury (though only mortality will be considered here). This, however, creates a number of problems.

The simplification in this approach becomes evident when one realizes that a human being is far more than a stream of income payments. This failure to consider nonpecuniary aspects of existence implies a gross undervaluation of a human life. A related objection is the seemingly unfair treatment accorded the very young, the very old, women (especially housewives), blacks and other groups with relatively low incomes. According to a strict interpretation of the human capital procedure, these individual's lives are worth less than those of individuals with higher incomes. This could have important repercussions when considering a disease that strikes a particular demographic group.

The methodology that is used in this study seeks to avoid such problems, making use of the following formula for estimating the human capital value, V, of a life saved:

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*"Measuring the Social Impact of Heart and Circulatory Disease Programs: Preliminary Framework and Estimates," Jan Paul Acton, Rand Corporation, R-1697-NHLI, April 1975.

$$V = \sum_{i=1}^{n} \frac{Y_i}{(1+r)^i} \qquad (3.1)$$

where:

Y_i is the average per capita annual income of residents of nonmetropolitan areas in the United States ($3,241).* These payments were assumed to be made in a lump sum at the beginning of each year throughout the course of a person's life. This helps eliminate some of the unfair valuation given the demographic groups cited above. This assumption circumvents the problem caused by the fact that deaths occur during the year thereby causing relatively small deviations in the amount of income lost during the course of the year.

r is the discount rate (6 percent). This is needed since the value of the dollar next year is not the same as the value of the dollar now. Rates between 4 and 8 percent are most commonly used in current economic studies.

n is the expected additional life span of the individual as determined from a life table. In the case of arrhythmia victims, it was assumed that the individual's life span would be shorter even if he or she survived simply because one heart attack increases the chance of another fatal heart attack. This shortening was based on data presented by Ruberman, et al.** In the case of all other trauma, normal life spans were anticipated. (This was done for both men and women, and then the two were averaged so as to take advantage of the different life spans for men and women.)

In this manner, values were readily computed. For arrhythmia, emphysema and motor-vehicle accident victims, these amounted to $24,000, $20,000 and $45,000 respectively. The difference between the first two and the third reflects the fact that the mean age of the motor vehicle accident victims is about 35 while the mean age of cardiac and emphysema victims is over 70.

In the case of burns, it was assumed that most burn deaths are accidental and that their ages followed the distribution of those killed in all accidents. The average value of the life of a burn victim was computed to be about $38,000.

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*"Non-Federal Physicians, Hospitals, Population and Income: County Statistics," Physician Distribution and Medical Licensure in the United States, 1975, Center for Health Services Research and Development, AMA, Chicago, 1976, pp. 169-323.

**"Ventricular Premature Beats and Mortality After Myocardial Infarction," William Ruberman, et al, reprinted from the New England Journal of Medicine, 297:750-757, October 6, 1977.

Poisoning, however, was considered to be a weighted average (based on national figures provided by the Division of Vital Statistics) of accidents, suicides, homocides and other external causes. Again, it was assumed that the distribution of burn deaths followed the distribution of the larger accident group. A figure of about $40,000 resulted. Comparison of the values of a human life by cause of death are shown in Table 3.3.

It should be noted that with respect to current economic literature, these values for human life are <u>extremely</u> conservative. Other studies place the value of human life as high as $250,000. But other studies generally either deal with only one type of death (e.g., airplane accident) or do not differentiate between various causes of death.

Since morbidity benefits have not been included, the system-independent benefits can be derived by using the following model:

$$TB = \sum_{j=1}^{T} \left\{ Z_j * (S_j - S'_j) * \sum_{i=1}^{N_j} \frac{Y_i}{(1+r)^i} \right\} \qquad (3.2)$$

where:

TB is the total benefits

T is the number of trauma types

j is the index referring to specific trauma types (cardiac fatal arrhythmia, burn, auto accident, etc.)

Z_j is the number of ambulance calls/year/trauma type

S_j is the fraction of victims that might be saved with improved communications

S'_j is the fraction of victims that might be saved without improved communications

N_j number of additional years life expected for a victim that is saved in trauma type j

TABLE 3.3 EQUIVALENT MONETARY VALUE OF A LOST HUMAN LIFE	
CAUSE OF DEATH	HUMAN CAPITAL EVALUATION OF A LIFE SAVED ($)
CARDIAC	24,000
AUTO	45,000
POISON	40,000
BURN	38,000
MEDICAL, EMPHYSEMA	20,000

Y_i is the average per capita annual income of residents of nonmetropolitan areas

r is the discount rate.

In addition to the benefits of advanced communications in EMS as discussed in the previous section, there may be other benefits or differential benefits that accrue to the individual type of communication system installed. These benefits can arise from either varying levels of service, quality of service or cost differentials among systems. In the three types of systems studied here, both types of system-dependent benefits arise.

While the three systems (i.e., the UHF, public telephone and satellite) are all capable of providing communication that is an improvement over the systems currently in use, there are some capacity differences. With either a public telephone or a nationwide satellite system, a paramedic, in cases of unusual problems, would be able to consult medical experts familiar with the particular problem virtually anywhere in the United States. This would be of great help to an average paramedic in a nonmetropolitan EMS. While it is feasible to establish the same contact by UHF through the local doctor and his telephone line, the more direct system is more efficient, saving both time and additional interpretation errors. It is likely to be cheaper. These benefit differences have not been calculated.

Another advantage of the public telephone system is that it allows the paramedic to call ahead while en route to the scene (if the patient is near a phone) and reassure the other people at the scene that he is on the way and possibly give instructions in first aid that should be started. The benefits of this feature are not easily measurable. Sufficient data to do so did not exist in the case study areas; therefore, while it is believed that this system may be more beneficial than the others in this respect, estimates of the amounts have not been included.

The other type of system-dependent benefits, the cost-effectiveness benefits, are discussed in detail in Section 3.2.1, The Cost Model, and Section 3.4, Generalization of Case Study Results. Because of the many variables involved in the final costing of each system, the savings of one system over another cannot be expressed as a single, fixed value. The cost effectiveness of the satellite system is discussed under varying assumptions of terrestrial radio range, terrestrial capital ownership possibilities and satellite system costs.

3.2.2 The Cost Model

The cost model is designed to provide the costs of the three alternative systems. In order to produce a reasonable comparison that is widely applicable, the model provides a cost estimate for the construction of a new system of each type, rather than considering, for instance, the conversion of a VHF system to UHF or other similar cost situations that may arise under individual district circumstances. Such information is necessary in doing cost comparisons between systems. For the terrestrial systems (i.e., the public telephone and UHF), the model considers the terrain type, the expected effective radio range for the given terrain type and the portion of the fixed equipment owned by the EMS, as well as the standard cost variables, in order to determine the average annual cost of the systems. Satellite costs for mobile and hospital ground stations and the connectivity costs (time charges for each use of the satellite repeater) are handled parametrically.

In dealing with communication systems of any type, there are a number of relevant cost calculations to be made. Among these are total capital expenditures, annual capital costs, annual operating expenses and the average annual costs. Since each of these costs is calculated from the same cost data, they are, of course, related; however, different proportions of the cost factors are used in each calculation. Therefore, the ordinal results of comparisons among systems may not be the same for average annual costs as they are for total capital costs.

The cost model assumes that the capital equipment will be amortized using straight-line depreciation over the life of that equipment; i.e., ten years for stationary equipment and five years for mobile units. This is to account for the fact that the mobile equipment is jostled over roads and receives other rough treatment, and therefore does not last as long as fixed equipment. The model further assumes that EMS providers will purchase their equipment and build towers. However, since similar services or other users of terrestrial radio communications equipment often share equipment, two levels of ownership for the stationary equipment are considered for the EMS. In the first level, the EMS owns 100 percent of the fixed equipment; in the second case, the provider owns only 50 percent of such equipment. In both cases, all of the mobile units are purchased for the EMS system.

As discussed in Section 3.2.1, The Benefit Model, all systems are treated as equal capacity systems. The costs, therefore, have been derived to provide the same service by UHF, public telephone and satellite systems. Cost calculations for the two fully terrestrial systems are similar in many ways and thus will be discussed together. Satellite system costs will be described in the section that follows. In each case, the number of mobile units required is the same and is generalized from the case study results. The major capital costs for stationary equipment in each of the terrestrial systems are a function of the number of repeater towers or radio telephone switching systems required and the number of emergency rooms requiring central equipment. The number of towers required by each area is, naturally, a function of the area itself--the actual terrain and the ability of the provider to procure the real estate necessary for optimal tower placement. Obviously, the development of such plans was not within the scope of this study. Therefore, the number of towers required in the nonmetropolitan United States was estimated. Because it is essential in emergency medical service that the entire area be covered, with no dead spots or gaps in the coverage, a conservative estimate was used.

The number of towers required for a particular area is determined by the equation:*

$$T = \frac{A}{2r^2} \tag{3.3}$$

where:

T is the number of towers required

A is the area in square miles

r is the expected radius of radio coverage in miles.

In actually determining the tower requirement for each area, the model also considers the terrain type of the area. The expected radio range is substantially affected by the terrain and, thus, terrain significantly affects the tower requirement. Accordingly, a range of expected coverage distances was used for each

*Private communications, Donald S. Bond, RCA Laboratories, Princeton, New Jersey.

terrain type. The specific ranges are shown in Table 3.4. Again, in order to ensure comprehensive coverage, conservative values have been used.

The range of coverage using a public telephone/RTSS is expected to be about the same as the range obtained by using the standard UHF equipment.* Therefore, the total tower requirement for the UHF system and the RTSS requirement are identical. There is some difference in the costing of the two because of the varying needs of the emergency room or base station. In the case of the public telephone system, the hospital needs only standard phone service, with enough direct lines into the emergency room to handle the calls from the mobile units. Since most of the hospitals encountered in the case studies had this capacity, it was assumed that this service exists in all the nonmetropolitan hospitals and these costs are not included in the model.

In the UHF system, the hospital requires the normal tower with receiving and transmitting equipment, plus a control unit for the emergency room. It is assumed that the tower at the hospital can be used to replace one of the repeater towers necessary to cover the area. Therefore, in the UHF system, the number of repeater towers is given by the following formula:

$$TR = TT - BS \text{ for } TT > BS \text{ or} \tag{3.4a}$$

$$TR = 0 \text{ for } TT \leq BS \tag{3.4b}$$

where:

TR is the number of repeater towers required

TT is the total number of towers required

BS is the number of base stations with control units. Note that this is equal to the number of emergency rooms in the area providing full emergency medical service.

*Private communications, Dan DuMont, Motorola, Houston, Texas.

TABLE 3.4 RADIO COMMUNICATION RANGES FOR VARIOUS TYPES OF TERRAIN		
TERRAIN TYPE	RADIUS OF COVERAGE LOWER LIMIT (MILES)	RADIUS OF COVERAGE UPPER LIMIT (MILES)
MOUNTAINOUS	10	20
HILLY	13	20
FLAT	25	30

SOURCE: PRIVATE COMMUNICATIONS, DONALD S. BOND, RCA LABORATORIES, PRINCETON, NEW JERSEY.

Costs for the terrestrial systems were obtained from Motorola, Dallas, Texas. This was done for a number of reasons. First, Motorola has a large share of the mobile communications market in the United States. Second, all of the EMS units contacted by ECON used some, if not all, Motorola equipment. In addition, most of the equipment was purchased on a least-cost bid basis, and therefore the prices must be assumed to be competitive. And, finally, since Motorola is a large, nationwide/worldwide firm, its prices are uniform regardless of the area of the country. Furthermore, since they deal directly with the purchasing agency, there is no confusion between wholesale and retail prices, "middleman" agreements, etc.

Cost figures for the UHF system were obtained from Dan DuMont of Motorola, Inc. Mobile ranges are estimated to obtain 90 percent coverage 90 percent of the time. A system using a completely portable unit was costed when the required range was 15 miles or less (10 miles in mountainous areas) and a system with a portable radio with a vehicular repeater was used when the range requirement was from 16 to 30 miles (11 to 20 in mountains). The maintenance costs included were those of the contract price of Motorola's maintenance agreements. All units have a ten full-duplex voice channel capacity. Specific capital cost estimates can be seen in Table 3.5.

The annual operating costs for each system are presented in Table 3.6. Motorola maintenance agreement prices are used in the case of the UHF repeater system and the mobile units of the public telephone system. The agreement prices were supplied by Dan DuMont of Motorola, Inc. Other costs for the public telephone system are derived from the Texas case study, as reported by Dr. James Finney of Trinity Medical Services Associated, Inc. and Tim Thomas, Sr. of Thomas Electronics, Inc.*

Total annual costs for the two terrestrial systems were, in the case-study areas, 4 percent of the total capital costs in the UHF system and 3 percent of the total capital costs in the public telephone system. (Note that the phone lines used in the public telephone system are maintained without explicit charge to the EMS provider by the telephone company.) These averages (3 and 4 percent) are used in the model to estimate annual operating costs for the terrestrial systems.

The model does not include the following costs associated with the terrestrial systems:

- The cost of real estate for tower erection
- The cost of remote power
- Long-distance telephone charges, where necessary.

The satellite system has three basic cost components: (1) the average capital cost of ground stations (fixed and mobile), (2) the connectivity cost of satellite communications time, and (3) the annual maintenance cost for the provider-owned equipment. Since preliminary cost estimates for the satellite system are not yet available, the model handles these costs, with the exception of the maintenance costs, parametrically. The maintenance cost of the ground equipment is assumed

*The affiliations (and phone numbers) of persons named in the text are listed in Appendix C of this report.

TABLE 3.5 BREAKDOWN OF CAPITAL COST ESTIMATES FOR TERRESTRIAL SYSTEMS

UHF		PUBLIC TELEPHONE	
BASE STATION:		BASE STATION:	
TRANSMITTER	$10,000	HOSPITAL TELEPHONES*	
ANTENNA WIRE	1,000		
HOSPITAL CONTROL UNIT	14,000		
TOWER	4,300		
TOTAL	$29,300		
REPEATER TOWERS:		REPEATER TOWERS:	
TRANSMITTER	$10,000	RTSS	$25,000**
ANTENNA WIRE	1,000	TOWER	4,300
TOWER	4,300	TOTAL	$29,300
TOTAL	$15,300		
MOBILE:		MOBILE:	
PORTABLE	$ 5,000	PORTABLE	$ 5,070***
OR		OR	
PORTABLE WITH VEHICULAR REPEATER	$11,000	PORTABLE WITH VEHICULAR REPEATER	$11,070***

SOURCE: PRIVATE COMMUNICATIONS WITH DAN DUMONT, MOTOROLA, INC., DALLAS, TEXAS, EXCEPT AS NOTED.

*COST NOT INCLUDED IN MODEL.

**SOURCE: PRIVATE COMMUNICATIONS WITH TIM THOMAS, SR., THOMAS ELECTRONICS, INC., FORT WORTH, TEXAS.

***INCLUDES MODIFICATION COSTS TO STANDARD UHF EQUIPMENT ($70). ESTIMATE BY TIM THOMAS, SR., THOMAS ELECTRONICS, INC., FORT WORTH, TEXAS.

TABLE 3.6 BREAKDOWN OF ANNUAL OPERATING COST ESTIMATES FOR OPERATING SYSTEMS

EQUIPMENT	ANNUAL MAINTENANCE COST (DOLLARS PER YEAR)	OTHER ANNUAL COSTS (DOLLARS PER YEAR)
UHF SYSTEM		
TOWER	300	
BASE STATION	900	
UHF REPEATER	600	
PORTABLE UNIT	144	
VEHICULAR REPEATER	144	
PUBLIC TELEPHONE SYSTEM		
RTSS	200	
TOWER	300	
PORTABLE UNIT	144	
VEHICULAR REPEATER	144	
INTERCONNECT MOBILE TO STANDARD PHONE SYSTEM		475 PER RTSS
LONG DISTANCE VARIES WITH NUMBER OF CALLS AND AVERAGE DISTANCE TRAVELED; NOT INCLUDED IN MODEL.		

to be 4 percent of the total capital costs, in line with the two terrestrial system costs. The model does not include start-up costs, learning effects, system-transition costs or other such costs associated with the satellite system.

In general terms, the model operates as follows:

<u>UHF System Annual Cost</u>

$$\text{ACUHF} = \left\{\begin{array}{l}\text{Annual Capital and}\\ \text{Maintenance Cost}\\ \text{Including Ownership}\\ \text{Portion of Towers}\end{array}\right\} + \left\{\begin{array}{l}\text{Base Stations Plus}\\ \text{Annual Capital and}\\ \text{Maintenance Costs}\\ \text{of Mobile Units}\end{array}\right\}$$

$$ACUHF_r = \left[\frac{1}{LF} + \beta\right] * \alpha * \left[CT * \left\{\sum_{t=1}^{3} \frac{A_t}{2R_{r,t}^2} - BS\right\} + CB * BS\right] + \left[\frac{1}{LM} + \beta\right] * C_r \tag{3.5}$$

$$\text{where } C_r = \begin{cases} CVP * (V_{t=2} + V_{t=3}) + CMV * V_{t=1} \\ CMV * (V_{t=1} + V_{t=2} + V_{t=3}) \end{cases}$$

Public Telephone/RTSS Annual Cost

$$ACRTSS = \left\{\begin{array}{l}\text{Annual Capital and Maintenance} \\ \text{Cost of RTSSs Including Owner-} \\ \text{ship Portion}\end{array}\right\} + \left\{\begin{array}{l}\text{Annual Capital and} \\ \text{Maintenance Costs} \\ \text{of Mobile Units}\end{array}\right\}$$

$$ACRTSS_r = \left[\frac{1}{LF} + \beta\right] * \alpha * \left[CS * \sum_{t=1}^{3} \frac{A_t}{2R_{r,t}^2}\right] + \left[\frac{1}{LM} + \beta\right] * C_r \tag{3.6}$$

Satellite System Annual Cost

$$ACSS = \left\{\begin{array}{l}\text{Annual Capital and Maintenance} \\ \text{Costs of Fixed and Mobile} \\ \text{Ground Stations}\end{array}\right\} + \left\{\begin{array}{l}\text{Annual} \\ \text{Connectivity} \\ \text{Costs}\end{array}\right\}$$

$$ACSS = \left[\frac{1}{LM} + \beta\right] * CG * \left[BS + \sum_{t=1}^{3} V_t\right] + CC * CM \tag{3.7}$$

Cost Effectiveness

Annual cost savings from use of a satellite system rather than alternative terrestrial systems:

$$CE = ACUHF_r - ACSS$$

$$CE = ACRTSS_r - ACSS$$

where:

LF is the stationary equipment life

β is the maintenance fraction (0.04 for UHF, 0.03 for RTSS, 0.04 for satellite)

α is the portion of the stationary equipment owned by EMS

CT is the capital cost of the repeater tower

A_t is the area (in $mile^2$) within terrain type t

$R_{r,t}$ is the effective radio range over terrain type t

CB is the capital cost of a base station (radio tower and hospital control unit)

BS is the number of required base stations

LM is the mobile equipment life

CUP is the capital cost of a portable mobile unit

CMV is the capital cost of a portable mobile unit and a vehicular repeater

V_t is the number of emergency vehicles required in terrain type t area

CS is the capital cost of an RTSS

CG is the capital cost of a mobile ground unit of satellite system

CC is the satellite system connective charge per channel minute ($/minute)

CM is the number of channel minutes required (a function of the number of ambulance trips)

CE is the cost effectiveness

r is the communication system range category.

Cost effectiveness is determined by comparing the total annual costs of different systems. Total annual costs consist of the annual capital and operating costs plus the "use" cost of the system, if it is appropriate. The magnitude of the cost effectiveness is thus the magnitude of the difference between the total annual costs of any two systems. By considering the upper and lower limits of the expected radio coverages, as previously described, and the possibilities of the EMS provider owning 100 percent or 50 percent of the stationary ground equipment in the two terrestrial systems, and by making comparisons to a satellite system, eight different cost-effectiveness tables are derived. These (Tables 3.30 through 3.37, inclusive) are included with and explained in later discussion.

3.2.3 The Traffic Model

In addition to the cost of the communication system and the benefits such a system will provide, it is important to know how much the system will be used; i.e., the volume of the system traffic. This factor is perhaps most conveniently measured in terms of the number of channel minutes that will be required in a given period of time. This information is essential in designing an operational system in order to determine the required capacity for EMS and to determine whether or not it would be feasible for other applications such as forest fire fighting or law enforcement to share a communication system. Additionally, this information will be important in establishing tariffs. In doing so, it is, of course, necessary to set prices for use of the service within a range that is affordable to the EMS provider. At the same time, it is essential for the revenue from the actual number of calls at the specified price to recover all the costs of the system. These costs include the construction, operation and maintenance costs of the system. In the private sector, tariffs also are used to recover research and development costs, but in the public sector it is standard policy to consider these costs as a sunk investment cost.

In emergency medical services, the volume of traffic in terms of channel minutes per year is a function of a large number of factors. On the micro-level, the length of time required by each emergency call is determined by certain aspects of that particular situation. These include:

- The trauma type
- The severity of the trauma and complications
- The diagnosis and treatment required
- The distance to and from the scene of the incident
- The distance to the receiving hospital from the scene, if not the same as origin of the provider

- The paramedic's skill, background and experience with the type of trauma
- The doctor's confidence in the paramedic
- The state laws governing the actions of the health personnel involved
- A large number of other factors specific to the incident.

Obviously, with so many highly variable factors involved, the durations of the communications required for dispatch and telemetry for a medical emergency call can be substantially different.

This data (the duration of communication per call) is of little or no interest in terrestrial systems, where the frequency of calls is low enough not to cause serious frequency allocation problems; hence, the data has not been collected for the nonmetropolitan areas of the United States. Accordingly, experts in each case study who have a great deal of experience with the established systems and with emergency medical cases in general were asked to give estimates of the average number of minutes required by trauma. In many cases, figures were collaborated by paramedics, emergency room physicians and by EMS provider administrators. In addition, the experts were asked to state the proportion of all emergency calls (by trauma type) that they believed would require advanced communications. Estimates from each of the case study areas were used in developing a weighted average for the communication requirements for emergency calls in the nonmetropolitan United States.

The total number of channel minutes required for EMS in the nonmetropolitan United States is influenced by a number of factors, including the following:

- The number of emergencies by trauma type
- The transport rate
- The average number of channel minutes per call by trauma type.

It is important to note the difference between the number of emergencies of a given trauma type and the number of emergency calls for that trauma type. In the case study areas, on average, overall trauma types account only for between 10 and 13 percent of the emergency victims arriving at the emergency room by ambulance. This proportion is referred to here as the transport rate. Other victims arrive at the emergency room by private car, cab, police transport, on foot, by public transport, etc. The transport rate does vary substantially by trauma type. Those types with high transport rates include serious injuries due to burns or automobile accidents and sudden medical problems, while lower rates are found in more chronic medical problems and less serious injuries. The scene of the incident, whether industrial, residential, highway or remote, and the distance to the nearest emergency room also affect the transport rate. However, the introduction of a specific type of communication system will not change the transport rate. Therefore, where national statistics on the number of emergency calls per year for a specific trauma type were not available (e.g., in emphysema), the necessary information was derived using the number of emergencies of the given type and the transport rate as experienced in the case study areas.

Table 3.7 gives the estimated annual traffic for emergency medical communication in the nonmetropolitan United States. Each emergency call requires dispatch and hospital recurring coordination instructions. These communications take, on average, five minutes; however, since this can be accomplished over a half-duplex channel, only 2.5 (full) channel minutes are required per call. The number of channel minutes per year is derived as a weighted average of the relevant data from the case studies.

TABLE 3.7 ESTIMATED ANNUAL TRAFFIC FOR EMS COMMUNICATION IN THE NONMETROPOLITAN UNITED STATES

TRAUMA TYPE	ESTIMATED NUMBER OF CALLS REQUIRING DISPATCH	NUMBER OF CALL/YEAR REQUIRING TELEMETRY (SITE AND/OR TRANSIT)	ESTIMATED CHANNEL MINUTES REQUIRED PER YEAR
CARDIAC	114,906	101,015	2,098,779
AUTO			
SHOCK	100,360	29,861	698,815
HEAD AND SPINAL	56,216	18,022	492,167
MEDICAL			
EMPHYSEMA	7,615	2,856	47,598
POISONING	14,049	4,948	84,602
BURNS	12,240	4,262	105,185
TOTAL	305,386	160,964	3,527,146

The total of 3.5 million channel minutes per year refers to the requirements for the example trauma types only. Table 3.8 gives an estimate of the percentage of all emergency room incidents that fall into these categories. While these trauma types taken together are only slightly over one quarter of all the emergencies, it cannot be said that benefits or traffic for the trauma types would be proportionally increased. This is because the benefits and traffic are largely dependent on the nature of the trauma itself.

3.3 The Case Studies

The case study sites were selected according to the procedure discussed in Section 3.1. The following criteria were determined to be important in the selection of the user samples:

TABLE 3.8 PERCENTAGE OF ALL MEDICAL PATIENT EMERGENCIES FOR SELECTED TRAUMA TYPES

TRAUMA TYPE	ESTIMATED PERCENT OF ALL EMERGENCIES
CARDIAC	6.0
AUTO (TOTAL)	19.8
AUTO (NONMINOR)	8.0
EMPHYSEMA	0.5
POISONING	0.8
BURNS	0.6

- Market aggregation potential
- Data availability
- The magnitude of potential traffic
- The probability of early commercialization
- The feasibility of experimental verification.

An extensive search revealed that data availability would be the overriding consideration in the selection of user samples. The case study sites were: central Texas, north central West Virginia and southeast Mississippi. ECON collected the relevant data for each case study. In addition, detailed interviews were conducted with a large number of emergency room physicians, EMS provider administrators, paramedics, researchers and hospital administrators who are associated and familiar with the operations of the emergency medical service under study.

It is of value to note that, at each case-site area, there are plans to improve the data availability within the next year both by continuing and improving existing data collection and by adding other measurements of the system's efficiency and effectiveness. In each case, this work is being done under government grants, primarily from DHEW, DOT and other federal agencies. It is believed that within the next year, or next few years, data will be available to verify the estimates used in this study and to measure the impact of an improvement in communications for emergency medical services on patient morbidity.

3.3.1 The Texas Case Study*

The site selected is near Fort Worth, Texas and is an emergency medical service district composed of eight counties in total. For the purposes of this study, only six of those counties were considered as the sample area. In three of the eight counties, only one of which is in the six counties considered in the sample, a system linking the paramedics to the public telephone service has been established. Expansion of the service to all eight counties is planned. To date, funding for the EMS communication system has consisted entirely of federal grants. All eight counties make extensive use of the advance care hospitals located in Tarrant county, which includes Fort Worth and is not one of the counties included in the sample site. The area within the six counties covers, roughly, 4,500 square miles. The terrain is mixed; primarily flat to rolling hills, with some mountainous areas along the western side of the region. About 120,000 people live within the six county area, at an average population density of 26.1 persons per square mile. Population densities of the counties within the sample areas range from 14.7 to 39.9 persons per square mile. These population densities are low, relative to all nonmetropolitan counties in the United States.

As recently as four years ago, there was no centralized organization for EMS. Private ambulance services run by funeral homes provided the majority of emergency medical services. In general, the service quality was poor and there were even reported cases of multiple-victim accidents where dead victims were

*A complete listing of persons contacted is contained in Appendix C.

transported before the survivors. This points out the obvious conflict of interest in funeral homes running emergency medical services.

In discussions with experts at Trinity Emergency Medical Services Association, Inc. (hereafter called Trinity), it was determined that all of the counties, with the exception of Tarrant and possibly Johnson, experienced similiar problems and, in fact, similar EMS situations in general. They believed that in terms of distance traveled per run, the type of accidents, the percentage of calls using emergency medical services and relative frequency of call by time of day, etc., all six of the counties included in the sample site were homogeneous.

Figure 3.5 shows the Texas sample site and the population density of each county within the area.

It should be noted that three of the six counties in the sample area (Wise, Parker and Hood) are actually categorized by the Department of the Census as metropolitan or as being inside Standard Metropolitan Statistical Areas (SMSA). These counties have been included in the sample, even though they are metropolitan counties, because of the demographic characteristics of those areas. Each of the counties has a very low population density--considerably lower than the population densities of many of our other sample counties. In addition, they were included because of data limitations. The only nonmetropolitan county for which consistent data was available was Palo Pinto County. It is believed that the inclusion of Wise, Parker and Hood Counties, each of which had consistent and extensive data, was valuable from an information standpoint. It should be noted that the classification of metropolitan counties is based on a statistical evaluation of an area as a whole; therefore, Tarrant County, with a very large population density of 846.8 persons per square mile, easily outweighed the lower population density of the counties near it. Therefore, the average population density across

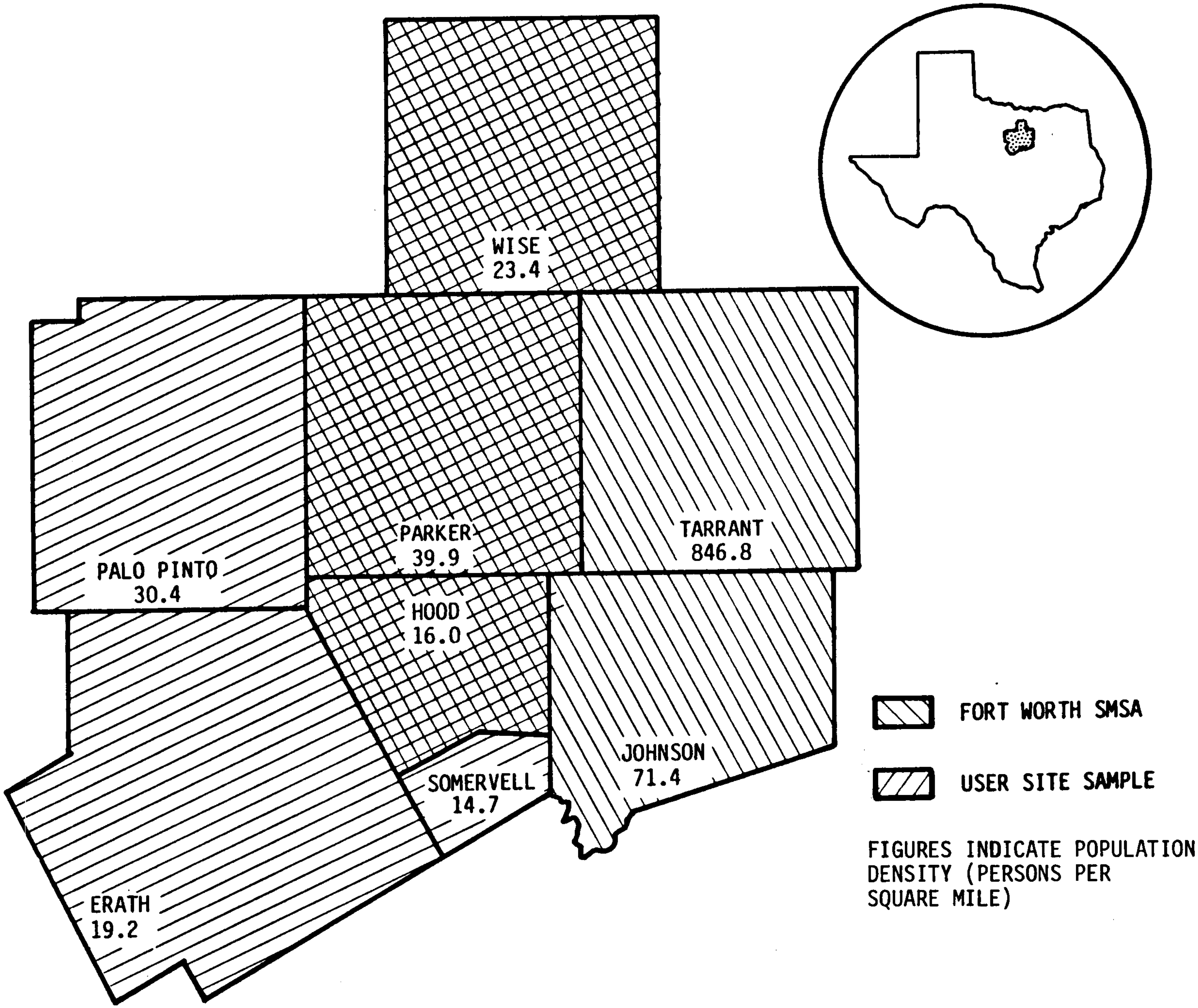


FIGURE 3.5 MAP SHOWING TEXAS COUNTIES SELECTED FOR EMS STUDY, WITH POPULATIONS

the Fort Worth SMSA, which includes Tarrant, Johnson, Hood, Parker and Wise Counties, is high enough to be classified an SMSA. However, taken separately, Wise, Parker and Hood Counties are decidedly rural in nature.

Trinity EMS is a large, efficiently-run association of EMS providers and hospitals in the eight-county district. Within this area, there are nine major emergency service hospitals; however, there are no advanced-care type of hospitals within the six-county area selected as a user sample. The effect of this is to force each of the sample counties to make extensive use of the Tarrant County facilities. Therefore, average run distances for seriously-injured patients are great. Trinity estimates that the average round-trip mileage per run is about 40 miles in all counties except Tarrant, where round-trip distance is thought to be about 16 miles. All major burn victims from the area (at least those with second-degree burns covering 30 percent or more of the body) are taken to the Dallas Burn Center, about 40 miles away, for definitive care.

Paramedics in the area are given a set of protocols to follow. These include a wide range of treatment types. Aggressive therapies such as defibrillation, active fluid replacement and drug therapies are available for use with physician consent. Regular use of the communication system has made these treatments standard practice. Use of the communication system also allows the physician in the emergency room to alter the treatment suggested in the standing orders if he feels the situation warrants it. Benefits from such flexibility depend strongly on the individual physician and his confidence in the paramedic at the scene.

In order to access the Trinity communication system, a paramedic dials the first two letters of the county that he is in and the first two letters of the victim's problems type (burn (BU), baby (BA), etc.). This automatically switches him, through RTSS, to the nearest receiving and resource hospital for the particular trauma type. This allows all parties to be aware of the patient's problem, vital information, expected emergency room (ER) arrival time and treatments administered. This allows for both the best available care and saves valuable time at the ER.

At present, the organization is in the process of converting from a group of locally run VHF ambulance companies to a unified system utilizing the public telephone network. Dispatch is still by VHF, but Trinity now has a total of four radio telephone switching stations. Only one of these is in the sample site (refer to Figure 3.5) and covers a large part of one county. Where there is use of the RTSS, Trinity also has use of advanced life-support equipment.

Table 3.9 presents the hospital categorization scheme for the Trinity area and Table 3.10 shows the hospitals that fall in the sample counties. Each of the hospitals listed receives some emergency patients. Services may be limited in the severity or types of trauma that they accept. In addition, many of the emergency rooms are not full-time. Physicians and nurses may be available only on call some times during the day or week. Because of this, many patients will be taken to a primary care facility, stabilized and transferred immediately to a more advanced care center. Other patients will be taken directly to a major emergency service. A communications network which encompasses each hospital can be instrumental in determining the appropriate course of patient transport when the capability of one hospital to handle the emergency is in question.

The major interviews in the Trinity area were held with and estimates were obtained from the following persons:

- Dr. James W. Finney, Project Administrator
- Dr. Alan Mickish, Medical Director
- Mr. Tim L. Thomas, Sr., Communications Expert

TABLE 3.9 HOSPITAL CATEGORIZATION SCHEME			
SCOPE OF CAPABILITIES	MAJOR EMERGENCY SERVICE	GENERAL EMERGENCY SERVICE	BASIC EMERGENCY SERVICE
TYPES OF EMERGENCIES	ALL	MOST	FEW
STAFFING			
EMERGENCY DEPARTMENT			
FULL-TIME DIRECTOR	REQUIRED	RECOMMENDED	OPTIONAL
OTHER PHYSICIANS	READILY AVAILABLE	READILY AVAILABLE	READILY AVAILABLE
REGISTERED NURSE	READILY AVAILABLE	READILY AVAILABLE	READILY AVAILABLE
OTHER NURSING PERSONNEL	READILY AVAILABLE	IN-HOSPITAL	AVAILABLE
SUPPORT SERVICES			
LABORATORY SERVICES	IN-HOSPITAL	READILY AVAILABLE	AVAILABLE
BLOOD BANK	IN-HOSPITAL	READILY AVAILABLE	OPTIONAL
RADIOLOGY	IN-HOSPITAL	READILY AVAILABLE	AVAILABLE
ANGIOGRAPHY	IN-HOSPITAL	OPTIONAL	OPTIONAL
OPERATING ROOM	READY AND STAFFED	READILY AVAILABLE	AVAILABLE
RECOVERY ROOM	READY AND STAFFED	OPTIONAL	OPTIONAL
INTENSIVE CARE UNITS			
FACILITY	REQUIRED	REQUIRED	OPTIONAL
STAFF	REQUIRED	REQUIRED	OPTIONAL

TABLE 3.10 HOSPITALS IN THE TEXAS STUDY AREA		
COUNTY	HOSPITAL	CATEGORIZATION
ERATH	DUBLIN HOSPITAL	BASIC EMERGENCY SERVICE
	STEPHENVILLE HOSPITAL & CLINIC	GENERAL
HOOD	HOOD GENERAL HOSPITAL	BASIC
PALO PINTO	PALO PINTO GENERAL HOSPITAL	GENERAL
PARKER	CAMPBELL MEMORIAL HOSPITAL	GENERAL
SOMERVELL	MARKS-ENGLISH HOSPITAL	BASIC
WISE	DECATUR COMMUNITY HOSPITAL	BASIC
	BRIDGEPORT HOSPITAL	BASIC

- Mr. Bryan Bledsoe, Training Coordinator
- Dr. Charles Crenshaw, Clinical Consultant
- Mr. Gus Schumann, Data Processing
- Mr. Marvin G. Moore, Public Relations.

Many of these interviews were held during a visit by ECON to Trinity during July 1978.

Within the area, a large number of statistics were collected on the number of runs by type of emergency, time of day, day of week, etc. In addition, the paramedic was asked to record the distance traveled, treatment administered and the condition of the patient at the scene and on arrival at the hospital. The data collection form required of each emergency run is shown in Figure 3.6. This data is compiled by computer. Data collection and analysis of hospital patient follow-up information has also begun at Trinity, but at the time of these interviews, this morbidity information was not complete enough to be used to estimate national trends.

According to those associated with Trinity, about 13 percent of all the cases seen in the emergency departments of area hospitals are delivered by the EMS providers. Others arrive by private car, on foot, by taxi, by police transport, etc. Only those who use the EMS will benefit from an advanced communication system. Increasing the number of people using an EMS system would increase the benefits of any part of that system. However, since the use of an advanced communication system will not increase the use of the EMS system, the number of transported victims has been held constant in this study. Additional benefits from an increase in users will accrue to a program of public education in EMS access and first aid.

The increased percentage of salvageable victims given here was estimated for the six-county sample area by experts at Trinity EMS, based on their

TRINITY EMERGENCY SERVICES ASSOCIATION
328 S. ADAMS FT. WORTH 76104
PHONE 817 335 9911

PATIENT NAME ______ SEX M ☐ F ☐ DATE ______
PATIENT ADDRESS ______ CITY ______ DATE OF BIRTH / AGE ______ PHONE NO ______
INCIDENT NO ______ ACTUAL LOCATION (PICK UP) ______ PHONE NO ______
RESPONSIBLE ADULT ______ ADDRESS ______ RELATION SHIP ______

PATIENT ASSESSMENT:

VITAL SIGNS
B P ___/___ ___/___
PULSE ______ ______
RESP ______ ______
TIME ______ ______

CONSCIOUSNESS: 01 CON 02 SEMI 03 UNC 04 CONFSD
BLEEDING: 01 NONE 02 MINIMUM 03 MODERATE 04 SEVERE
BREATHING: 01 NORMAL 02 RAPID 03 LABORED 04 ABSENT 05 SHALLOW
PUPILS: 01 EQ 02 UNEQ 03 CONSTRICTED 04 DILATED 05 NO RESPONSE 06 REACTIVE
WEIGHT (EST) ______

ALLERGIES ______

01 AGG ASSAULT
02 ALCOHOL
03 ASTHMA
04 AUTO ACCIDENT
05 BITE/STING
06 BURNS
07 CONVULSIONS
08 CUTS/BRUISES
09 DIABETIC
10 DROWNING
11 DRUG REACTION
12 DYSPNEA
13 ELECTROCUTION
14 EMER TRANS
15 EMPHYSEMA
16 FAINTED
17 FEMALE COMP
18 FLU
19 FRACTURE
20 G I COMPLAINT
21 GUN SHOT
22 HEAD INJURY
23 HIGH RISK INFANT
24 HYPERVENT
25 HYPOGLYCEMIA
26 MATERNITY
27 MUSCLE/SKELETAL
28 OVERDOSE
29 POISONING
30 PSYCHIATRIC
31 SHOCK
32 STABBING
33 STROKE
34 SUFFOCATION
35 SUICIDE
36 HEART
99 ______

LOCATION OF INJURY - ILLNESS
01 HEAD
02 FACE
03 EYE
04 NECK
05 BACK
06 CHEST
07 ABDOMEN
08 PELVIC REGION
09 UPPER EXTREMITY
10 LOWER EXTREMITY
11 RESPIRATORY
12 CARDIOVASCULAR
13 METABOLIC
14 MENTAL
99 OTHER ______

REMARKS ______

CARE PROVIDED:

ADVISING PHYSICIAN ______ PATIENT PHYSICIAN ______
EXTRICATION REQUIRED? Y YES N NO

BASIC CARE RENDERED:
01 BANDAGING
02 SPLINTING
03 TRACTION
04 PSYCH ASSISTANCE
05 MINOR BLEEDING CONTROLLED
06 O.B. TRANSPORT
07 VITAL SIGNS MONITORED
99 OTHER ______

BASIC LIFE SUPPORT:
01 SUCTION
02 OXYGEN
03 CPR
04 BURN COOLED/DRESSED
05 NECK IMMOBILIZED
06 SPINE IMMOBILIZED
07 ORAL AIRWAY
08 ASSISTED BREATHING
09 SHOCK
10 O.B. LIVE BIRTH
11 O.B. OTHER
12 MAJOR BLEEDING CONTROLLED
99 OTHER ______

ADVANCED LIFE SUPPORT
01 INTUBATED
02 EKG
03 TELEMETRY
04 IV
05 DRUGS
06 DEFIB SUC
07 DEFIB UNSUC
08 MAST TROUSERS
09 DEXTRO STIX
09 OTHER ______

INCIDENT AND RUN REPORT

AMBULANCE FIRM ______ CITY ______ HOSPITAL ______
☐ EMT ☐ ECA ☐ PARAMEDIC ☐ OTHER ______
DR. OR NURSE ______
SIGNATURE DOES NOT APPROVE OR DISAPPROVE ABOVE INFORMATION
☐ EMT ☐ ECA ☐ PARAMEDIC ☐ OTHER ______
RESPONSE CODE: OUT 1 3 IN 1 3
MILEAGE: OUT ______ IN ______

HOSPITAL:

INCIDENT NO. ______
ARRIVAL TIME ______

TYPE:
01 EMERGENCY
02 URGENT
03 NON URGENT
04 D.O.A.

DISPOSITION FROM ER:
01 ADMITTED ICU
02 ADMITTED
03 TRANSFERRED OTHER HOSPITAL
04 DISCHARGED WITH FOLLOW UP
05 DISCHARGED NO FOLLOW UP
06 DIED AFTER ARRIVAL

DATE: ______
TIME: ______

SERVICE PROVIDED IN ER: 01 LAB 02 X-RAY 03 MED

REASON FOR ADMISSION: ______

IF PATIENT ADMITTED: TYPE OF DISMISSAL
01 ROUTINE-HOME 02 AMA 03 TO OTHER HOSPITAL
04 ECF 05 EXPIRED 06 NURSING HOME
09 OTHER ______

DISMISSAL DATE ______

HOSPITAL COPY

FIGURE 3.6 DATA COLLECTION FORM FOR TRINITY EMS EMERGENCY RUN experiences with telemetry in the test area of Tarrant, Johnson and Wise Counties. Estimates for the counties further from the major care hospitals are significantly lower than experiences in the more central counties. These increases can be seen in Table 3.11. Estimates were made by Mr. Bryan Bledsoe and Dr. James Finney.

Cardiac arrhythmias are among the leading forms of cardiovascular disturbances, representing 47 percent of all myocardial infarctions which comprise, in turn, 45 percent of all "diseases of the heart." These trauma types lend themselves well to diagnosis by physicians not at the scene and, thus, to the use of EMS and telemetry systems.

The type of arrhythmia is determined by EKG. The terms "fatal" and "nonfatal" arrhythmias refer to the actual type of electrical heart irregularity experienced. "Fatal" arrhythmias include straight-line readings and two other very serious arrhythmia patterns, but does not necessarily indicate (as the name implies) that the patient is dead. "Nonfatal" arrhythmias are, in general, less serious types of electrical pattern irregularities but do, in many cases, cause death.

There were 7,668 emergency runs for cardiac victims in the Trinity area during 1977. Applying the above nationwide figures to the Trinity area yields an estimated 1,620 runs for arrhythmia victims in the Trinity area. To eliminate the figures for Johnson and Tarrant Counties, it was assumed that the percentage of total runs for arrhythmia that occurred in any one county could be represented by the percentage of total runs for all emergencies that occurred in that county. Thus, since 601 of 28,536 emergency runs occurred in Erath County, it was assumed that 601 divided by 28,536 equals 2.1 percent of the arrhythmia runs that occurred in Erath County. In this manner, a total of 122 emergency runs for arrhythmia victims were computed for the relevant six-county region.

TABLE 3.11 EXPECTED IMPROVEMENT IN SALVAGEABILITY FOR THE TRINITY EMS AREA

TRAUMA TYPE	EXPECTED PERCENT INCREASE IN NUMBER OF PATIENTS SALVAGED DUE TO ADVANCED COMMUNICATIONS (%)
ARRHYTHMIAS	
"FATAL"	24
"NONFATAL"	20
AUTO	
SHOCK, MAJOR CHEST, BLEEDING	54
HEAD AND SPINAL	30
OTHER	NO IMPACT
BURNS	
GREATER THAN 30% OF BODY	30
LESS THAN 30% OF BODY	10
MEDICAL	
DIABETIC SHOCK	10
EMPHYSEMA	20
STROKE	NO IMPACT
BEHAVIORAL	NO IMPACT
DRUG OVERDOSE	15
POISONING	25
NEONATAL	SYSTEM DEPENDENT

These figures were then classified as "fatal" (30 percent of the total) and "nonfatal" (70 percent). This distribution is important since the effect of telemetry is different for each of the above. Only 1 percent of the victims of fatal arrhythmias can be expected to live without telemetry, whereas 25 percent would survive if full use were made of it. In the case of nonfatal arrhythmia, 50 percent would survive without telemetry while 70 percent can be salvaged with its aid. Net salvages due to the use of telemetry can then be computed by use of the formula:

$$X * (Y_1 - Y_2) \tag{3.8}$$

where:

X is the number of runs

Y_1 is the percentage saved when telemetry is used

Y_2 is the percentage saved when telemetry is not used.

A total of 27 lives was found to be saved by the use of telemetry. If the computed value of $24,000 per life is used, these salvages represent a saving of $648,000 in the six-county region alone.

Shock, major chest trauma and hemorrhaging or major bleeding problems, as well as head and spinal injuries, are types of trauma often associated with automobile accidents. There may be some discrepancies in the recording of these trauma types as "auto," or by type, from one user sample to another. Efforts have been made to make the data collected as consistent as possible. Other automobile accident-related injuries for which an ambulance is called are usually less serious in nature (e.g., simple fractures without shock, cuts, bruises, etc.), and generally do not require telemetry of biomedical information.

Statistics necessary for benefit calculations for the use of telemetry in motor vehicle accidents (MVAs) were easily computed, since the data received from Trinity included both the number of MVAs in each county and the conversion factors relating the number of accidents to the number of injuries. For example, there were 717 MVAs in Palo Pinto County and one injury for every 3.1 MVAs, which yields a total of 231 injuries from MVAs in Palo Pinto County. It was also revealed that approximately 70 percent of all those injured in MVAs use EMS.

However, not everyone who makes use of an EMS system is in need of telemetry of vital signs or EKG. Roughly 60 percent of all injuries in the Trinity area were considered "minor," with telemetry having little (if any) effect. Thus, it is assumed that 60 percent of those transported, approximately 527 for the six-county region, do not require biomedical telemetry.

Telemetry is of great importance, however, for those victims suffering from severe shock or head and spinal injuries and who, according to Trinity, comprise 25 percent and 15 percent of the total, or 232 and 139 victims, respectively. Only 40 percent of the victims of severe shock are expected to survive without biomedical telemetry, while the use of telemetry raises this total to 64 percent. For those suffering from head and spinal injuries, telemetry increases the salvage rate from 25 percent to 50 percent.

The calculation of benefits was done separately for victims of shock and for victims of head and spinal injuries. A total of 55 and 29 lives were saved, respectively. At $45,000 per life, this represents savings of $2,475,000 for victims of shock and $1,305,000 for victims of head and spinal injuries.

"Burns" refers to second or third degree burns only. Of the 1,815 burn cases reported in emergency departments by Trinity, 36 had second or third degree burns covering at least 30 percent of the body (15 of whom were transported to the burn center). In addition, 262 individuals with burns covering less than 30 percent of the body required hospitalization. EMS utilization was computed from the information that 27 percent of burn victims are transported and that this figure doubles when at least 30 percent of the body is covered by burns. Johnson and Tarrant Counties were again eliminated via the proportionality rule. A total of 20 emergency runs for burn victims was computed for the six-county region.

Salvages were computed from the information that, when burns cover at least 30 percent of the body, 40 percent survive without telemetry and 70 percent survive with it, and when burns cover less than 30 percent of the body, 80 percent survive without telemetry and 90 percent survive with it. Only one telemetry-related salvage was computed for the Trinity area, for a net saving of $38,000.

Medical problems encompass a wide range of problems affecting a wide range of victims. Therefore, it is not appropriate to average the benefits of different types of medical problems. Medical problems include diabetic coma, stroke and emphysema. The choice of emphysema as an example rests primarily on the inapplicability of the alternatives. Diabetes Mellitus is a highly complex disease for which one cannot easily determine what constitutes a salvage. Stroke was also "unacceptable" because telemetry caused no change in the salvage rate because of the "slow" nature of a stroke itself. (According to Trinity, 50 percent survived whether or not telemetry was used.) Emphysema presented none of the above statistical difficulties.

Trinity provided information listing emergency runs by cause (including emphysema) and county for the period between March 1977 and April 1978. The data, however, was incomplete and it was necessary to scale the data to account for the missing counties, resulting in a total of 16 emergency runs in the six-county region.

Since only runs for emphysema are of concern, it was necessary to eliminate those cases in which there were cardiac complications (roughly 60 percent of all cases). This was done by assuming an even spread of complications and eliminating 60 percent of each county's runs.

Salvages were then computed using a formula and the information that--in the absence of cardiac complications--50 percent of victims would be expected to survive without telemetry and 70 percent would be expected to survive with it.

There were 2,400 poisoning cases admitted to emergency departments in the Trinity area, of which about 13 percent (312) were transported by EMS. Using the proportionality rule first proposed for cardiac cases, the transports were broken down by county, and Johnson and Tarrant Counties were eliminated, leaving only 37 transports for the six-county region.

Using the information that 60 percent of the poisoning victims would survive without telemetry while 75 percent would survive with it, a total of six telemetry-related salvages were computed. At a valuation of $40,000 per life, this represents a saving of $240,000.

Neonatal problems in Trinity EMS are transported with a nurse and a doctor riding in the ambulance. In such a system, the benefits of communications are limited to the benefits of facility coordination. However, in areas where transports are made with paramedics, the communications are extremely valuable.

All problems listed as "not impacted" in Table 3.11 would not be benefited by the telemetry of biomedical information; however, all transports are benefited by care facility coordination.

Table 3.12 presents a summary of the benefits from advanced communications in the Texas user sample. It is most important to note that the benefits presented here are the benefits from advanced communications in the indicated example areas only. "Cardiac" indicates electrical arrhythmias only. These example problem types taken together account for about one-quarter of all emergency runs by ambulance services. Extrapolation to the total number of runs based solely on the number of calls may not be valid because it is believed that,

TABLE 3.12 BENEFITS FROM ADVANCED COMMUNICATIONS FOR THE TEXAS STUDY AREA

TRAUMA TYPE	NUMBER OF RUNS PER YEAR	LIVES SAVED ANNUALLY	ANNUAL BENEFITS ($1,000)
CARDIAC, ARRHYTHMIA	122	27	648
AUTO			
SHOCK	232	55	2,475
HEAD AND SPINAL	139	29	1,305
MEDICAL			
EMPHYSEMA	16	3	60
POISONING	37	6	240
BURNS	20	1	38
TOTAL	566	121	4,766

particularly with cardiac, head and spinal and shock, expected benefits per run may be well above the average.

Obviously, the largest benefit area will be the areas commonly associated with automobile accidents. This is true for three reasons:

1. The high incidence of these types of trauma
2. The high percentage of increased salvageability
3. The likelihood of such accidents involving relatively young victims with high expected lifetime earnings if they are saved.

The introduction of advanced communications to the EMS system in the six county area is expected to save 121 lives per year. Using the human capital approach described for each example trauma type to approximate a value for these levels yields a total of $4,766,000 per year. It should be noted that the value of a human life used here is extremely conservative, relative to other figures quoted in current economic literature.

It is estimated by the experts at Trinity EMS that the use of telemetry for patients with fatal arrhythmias will be significantly greater than for other victims because of the frequent need to monitor the patient's vital signs and take EKGs during transport. In many cases in the sample area, this leads to a need for telemetry for one hour or more. In other types of trauma there is, in general, less need for telemetry after the vehicle leaves the site, unless a patient develops complications or loses stability. The estimated average need for dispatch and telemetry for trauma type is detailed in Table 3.13.

All emergency calls require dispatch. It is estimated that dispatch and hospital coordination requires, on average, five minutes per call total. This part of the communication requires only a 1/2 duplex channel. Thus, the expected channel requirement is for 2.5 channel minutes per call for dispatch. The telemetry requirements for full duplex channels for each type of trauma were estimated by

TABLE 3.13 NEED FOR EMS DISPATCH AND TELEMETRY FOR TEXAS STUDY AREA

TRAUMA TYPE	DISPATCH TIME (MIN/CALL)	AVERAGE TELEMETRY TIME AT SITE AND IN TRANSIT (MIN)	PERCENT OF RUNS REQUIRING TELEMETRY (%)	NUMBER OF FULL DUPLEX CHANNELS REQUIRED
CARDIAC, ARRHYTHMIAS				
FATAL	5	40	100	DISPATCH 1/2 TELEMETRY 1
NONFATAL	5	15	50-60	1/2, 1
AUTO				
SHOCK	5	15	30-40	1/2, 1
HEAD AND SPINAL	5	20	30-40	1/2, 1
MEDICAL				
EMPHYSEMA	5	10	30-40	1/2, 1
POISONING	5	10	30-40	1/2, 1
BURNS	5	15-20	30-40	1/2, 1

Trinity EMS and include the need for telemetry both at the site and in transport. The requirements for "cardiac" is a weighted average of the requirements for fatal and nonfatal arrhythmias as noted in Table 3.14.

The ambulance services of Trinity EMS divide the day into three even shifts. The frequency of runs during these three shifts was approximately equal. In other words, the greater relative frequency of one type of trauma seemed to be balanced by a lower relative frequency of another trauma type during any particular shift. Therefore, it is assumed that the frequency of calls is constant with respect to the time of day and that one would have an equal chance of receiving a call at any moment during the day or night.

The ratio of the average requirements for weekdays and weekend days gives some idea of the peak-to-average loading problem. Since some trauma types occur with greater frequency on the weekend and others occur at a relatively constant rate over the week, more channels will be required on the weekend. It is assumed that the communication system will need to maintain sufficient capacity to handle weekend traffic and will thus be forced into excess capacity during the week.

Trinity EMS was able to use existing towers to mount the RTSS and thus significantly reduce their costs. One of the towers used is a 1,000-foot high educational television tower.

The mobile units used by the paramedics are completely portable. Standard UHF portable units (Motorola) were modified by Thomas Electronics at a cost of $70 per unit.

The costs of interconnection to the public phone system and maintenance charges for the RTSS are strictly a function of the number of RTSSs in the system. These charges are $475 per RTSS per year for interconnection and $200 per RTSS per year for maintenance.

TABLE 3.14 EMS COMMUNICATION-CHANNEL TIME REQUIREMENTS FOR TEXAS STUDY AREA

TRAUMA TYPE	NUMBER OF RUNS PER YEAR		AVERAGE CHANNEL TIME PER RUN (MIN)		PERCENT OF RUNS ON WEEKENDS*	AVERAGE CHANNEL TIME PER DAY ON WEEKDAYS (MIN)	AVERAGE CHANNEL TIME PER DAY ON WEEKENDS* (MIN)
	DISPATCH	TELEMETRY	DISPATCH	TELEMETRY			
CARDIAC, ARRHYTHMIAS	122	84	2.5	22.5	29	6.1	6.1
AUTO							
SHOCK	232	81	2.5	15	50	3.4	8.6
HEAD AND SPINAL	139	49	2.5	20	50	2.5	6.4
MEDICAL							
EMPHYSEMA	16	6	2.5	10	29	0.3	0.3
POISONING	37	13	2.5	10	50	0.4	1.1
BURNS	20	7	2.5	15	50	0.3	0.7
TOTAL	566	240				13.0	23.2

*FRIDAY AND SATURDAY (APPROXIMATELY 29 PERCENT OF THE WEEK).

Long-distance charges were estimated by Trinity to be about $600 per year. When this system was installed, it was discovered that one hospital did not have the required multiple phone lines directly to the emergency room (ER). The hospital switchboard in use would have added to the number of busy signals received by the paramedics; therefore, trunk lines to the ER were added. These costs are not included.

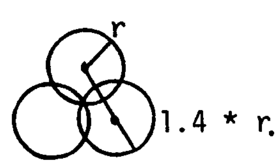
While the construction cost of this system, including towers, is in many cases slightly more expensive than that for the traditional UHF system, it provides the following additional benefits to the six-county user sample area:

- The ability to consult persons at the scene (if near a telephone) before the ambulance arrives and give advice on the appropriate first aid and estimated arrival time of the ambulance
- The ability to consult resource or receiving hospitals in Fort Worth or anywhere else in the county (or world) without additional towers (towers outside the sample area) or compatible radio equipment or frequencies.

However, in estimating the cost to construct a system of each of the three types, UHF, public telephone and satellite, for an area identical to the Texas user sample but without any existing communications network, one would consider the following.

A conservative estimate for the number of towers required to provide comprehensive coverage for either a UHF or public telephone system is obtained by allowing the towers to be spaced so that adjacent towers are placed about 1.4 times the expected range apart as shown:

where r = expected range



Thus, using Equation 3.3, the tower requirement of an area is approximately:

$$T = A/2r^2 .$$

The towers are 200 feet high and r is expected to be between 13 and 20 miles for both UHF- and RTSS-related equipment. The sample area would require a total of 14 towers with a 13-mile range or 6 towers with a 20-mile range. It is assumed that hospitals are placed so that their existing towers can serve as UHF repeater, or RTSS towers, as well as base stations. Thus, with 8 ERs, the sample area would require only six additional UHF or RTSS towers. The range for mobile units was discussed earlier. In this case, if the expected range is 13 miles, a completely portable unit would be used at a cost of $5,000 or $5,070 per vehicle for UHF and public telephone systems respectively. For a 20-mile range, however, a portable unit and a vehicular repeater would be necessary, costing $11,000 or $11,070 per unit respectively.

Of the eight hospitals in the sample area, three offer general emergency services and the remaining five offer basic services. If one actually were to construct a UHF or satellite system in this area, eight base stations would be required, one at each hospital. The costs of these systems are listed in Table 3.15 in the row specified as "8 Hospitals With Control Panels." Total capital costs range from $432,400 to $446,800 for UHF and $162,500 for a satellite system. However, in checking available national data on the number of emergency rooms by county, only three emergency rooms are recorded in the six-county area. Since the generalization of results to the entire nonmetropolitan United States is based on the national figures, estimates for costs in this sample area as they would appear in the generalization (if the generalization were done by county) are included here for comparison. Comparison of the figures (e.g., for UHF, 20 mile range: $432,000 with $347,100 and so forth) gives an idea of the relative conservatism of the estimates.

TABLE 3.15 COSTS OF ALTERNATIVE COMMUNICATIONS SYSTEM FOR TEXAS STUDY AREA, FOR 100% OWNERSHIP						
SYSTEM	CAPITAL COSTS (1977 DOLLARS)		ANNUAL OPERATING COSTS (1977 DOLLARS)		AVERAGE ANNUAL COST (1977 DOLLARS)	
	20 MILE	13 MILE	20 MILE	13 MILE	20 MILE	13 MILE
UHF REPEATER						
8 HOSPITALS WITH CONTROL PANELS	432,400	446,800	14,484	19,392	77,524	73,072
3 HOSPITALS WITH CONTROL PANELS	347,100	376,800	12,384	17,892	66,894	64,572
PUBLIC TELEPHONE (RTSS)	375,060	512,926	12,360	17,568	69,792	79,133

The estimates of capital and operating expenses for the construction of both UHF and public telephone (RTSS) systems are given in Table 3.15. For the UHF system, the average annual costs for the 20-mile range is greater than for the 13-mile range estimate. This seems paradoxical but, in fact, this would be the case. The variation comes from the relatively large difference in mobile equipment costs ($5,000 for a portable unit in the 13-mile range case and $11,000 for a portable unit with a vehicular repeater in the 20-mile range case) and the assumption that mobile equipment will have only a five-year life. Thus, every year the sample area would pay, in the 20-mile range case: 20 percent of $11,000/vehicle times 18 vehicles, rather than (in the 13-mile range case) 20 percent of $5,000/vehicle times 18 vehicles, which more than offsets the difference in annual costs (10 percent per year) of the additional UHF repeater towers.

The satellite EMS system would need to allow the paramedic (1) fully portable transmission of vital signs and EKGs from the patient (rather than the vehicle) at the scene of the trauma and (2) transmission of the same information from a moving ambulance en route to the nearest receiving hospital. In addition, simultaneous two-way voice conversations are required between the paramedic at the scene, the nearest receiving hospital and a resource or advanced-care hospital. Similar communications are required between the paramedic and the two hospitals when the ambulance has left the scene and is en route to the receiving hospital. In addition, the EMS provider or ambulance service must be integrated into the system for dispatch and care facility coordination.

The general notation for calculation of satellite-system costs is:

$$\text{Total Capital Costs} = \left[\text{Number of Vehicles} * \text{Cost of Mobile Unit}\right] + \left[\text{Number of Hospitals} * \text{Cost of Hospital Unit}\right].$$

By using straight-line depreciation and a ten-year life for stationary equipment and a five-year life for mobile equipment, average annual capital cost is determined.

The annual operating cost is the sum of the connectivity costs and the maintenance costs. The connectivity costs are a function of the number of channel minutes required and the cost per channel minute. Since the scope of this study did not include the design of a satellite system, these costs are handled parametrically. Maintenance costs are assumed to be similar to maintenance on terrestrial systems and are estimated at 4 percent of total capital costs. The total annual costs (TAC) or average annual costs are given as the total of the average annual capital costs and the annual operation costs.

Since it is not useful to consider a satellite system for such a small area, cost estimates using a parametric approach to capital and connectivity charges for nonmetropolitan United States are presented in Section 3.4, Generalization of Case Study Results.

3.3.2 The West Virginia Case Study

The second new user sample selected during the course of this study lies in north central West Virginia. Both Pennsylvania and Maryland border this almost entirely mountainous region. The sample site itself covers about 5,800 square miles in 13 counties. The most heavily-populated area lies in the north central area of the region. Included in this area are the cities of Morgantown, Fairmont and Clarksburg. The area is moderately dense in population with an average of 63.0 persons per square mile. (The range for nonmetropolitan areas in the United States is from 0.3 in Alaska to 742.6 in Rhode Island.) The area is classified entirely nonmetropolitan by the Bureau of Census.

Its EMS system, in general, and the EMS communication system specifically, are not as far advanced as the system described in the Texas user sample, but there is some use of advanced life-support equipment, and there are plans to convert the system to UHF. The system has been designed and built largely with federal grants.

The region, pictured in Figure 3.7, is unusual in that it is actually two EMS districts, Regions VI and VII, that have been combined for administrative purposes. As noted on the map, the population densities by county show quite a wide range from 17.8 persons per square mile in Tucker to 207.1 in Marion county.

The area is still in the process of uniting and standardizing the squads, communication and data collection. EMS squads in Upshur County and the town of Phillipi are not included in the EMS system. Unfortunately, the lack of unity to date and lack of cooperation by a few individual providers, has led to pockets of limited data availability. It is expected that, within the next 12 months or so, the area will be fully cooperating, and consistent regionwide records will be available.

In other areas, however, Regions VI and VII have established standard, well-coordinated patterns. Some of these areas are: medical accountability, medical command, field procedures and paramedic protocol. When a call is received, a chain of medical command is put into operation to ensure the most efficient patient care. This chain of medical command in the area is depicted in Figure 3.8. Medical command in the West Virginia sample area follows the process pictured in the diagram.

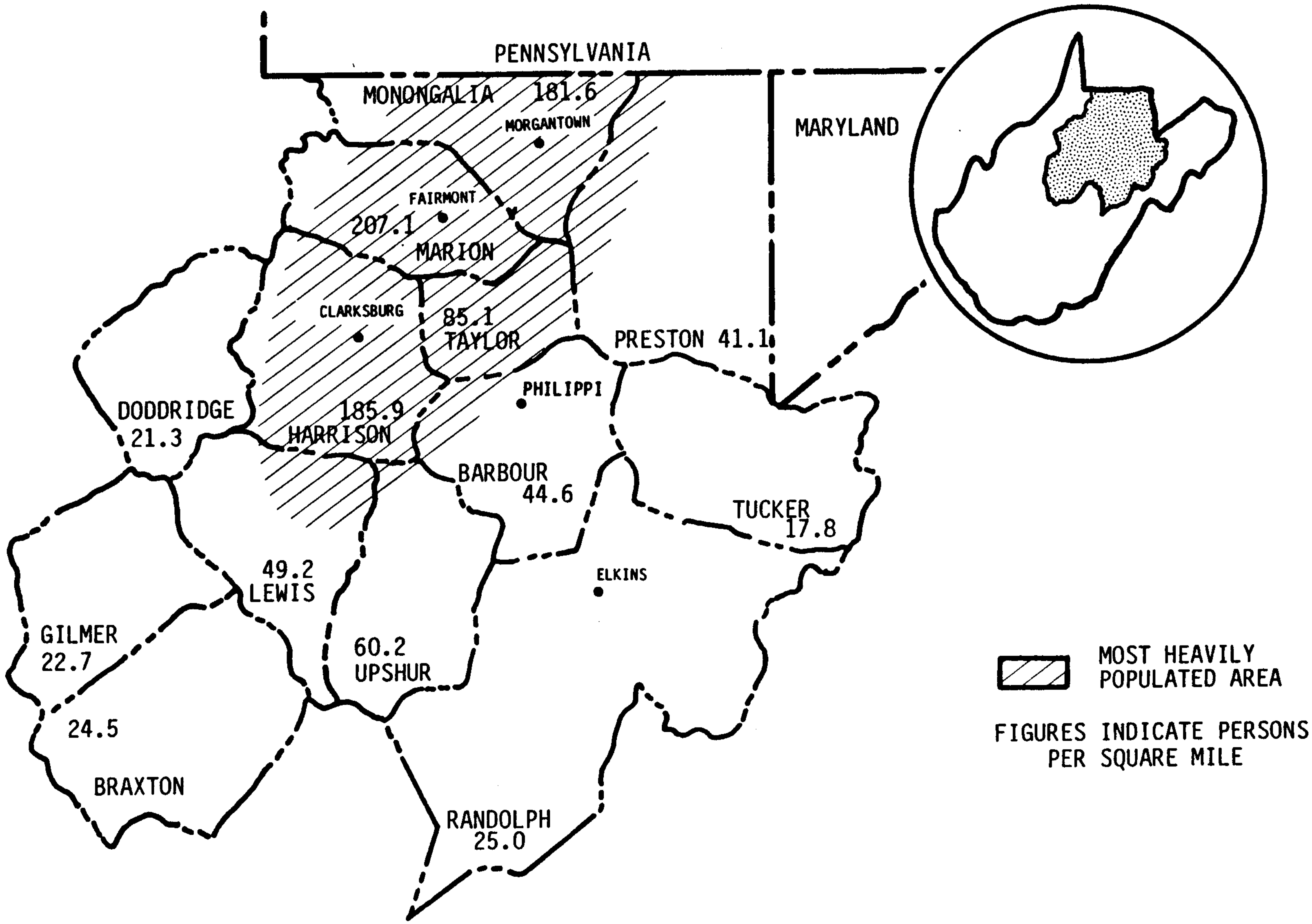


FIGURE 3.7 MAP SHOWING WEST VIRGINIA COUNTIES SELECTED FOR EMS STUDY, WITH POPULATIONS

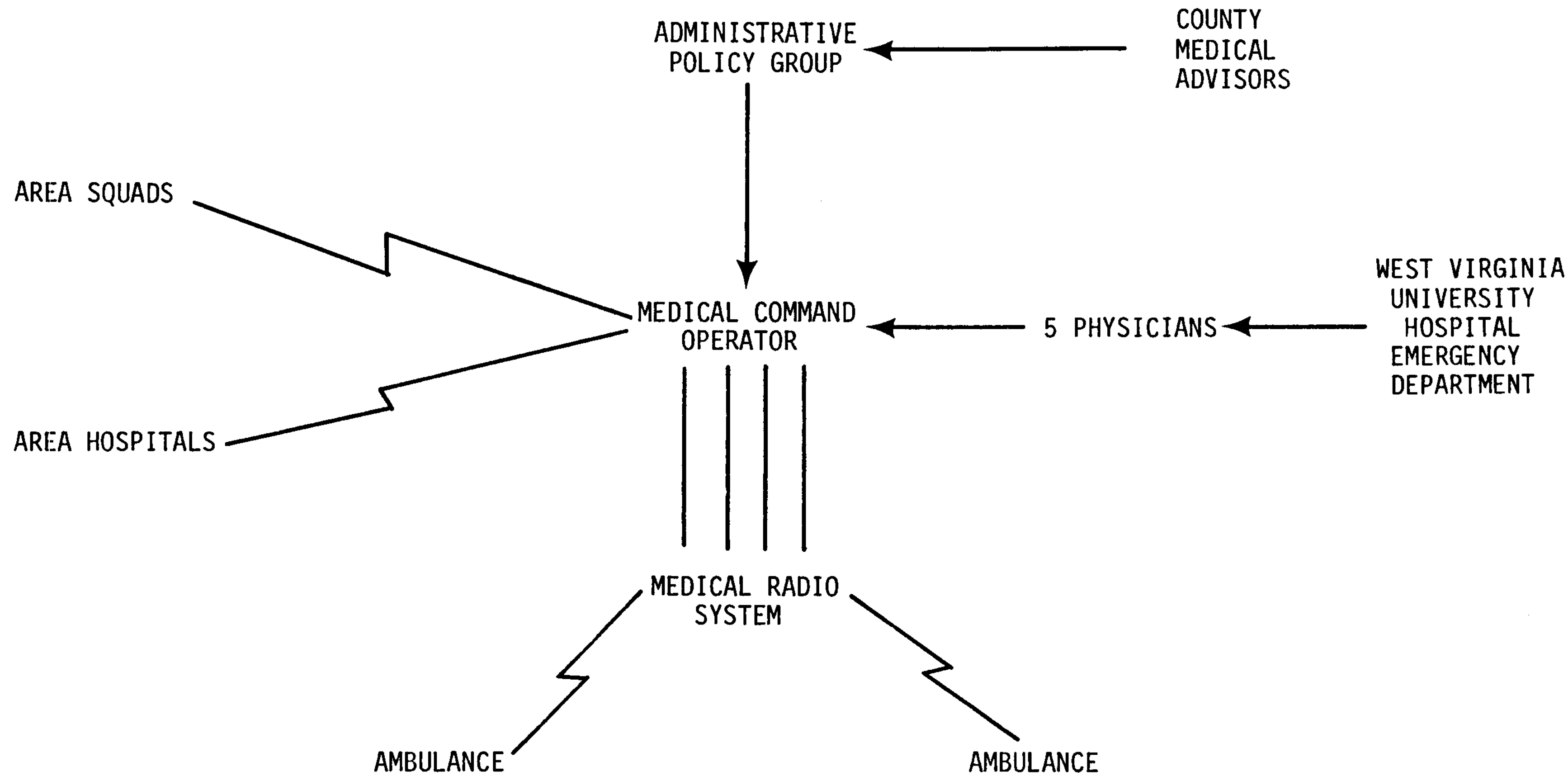


FIGURE 3.8 MEDICAL COMMAND ORGANIZATION IN THE WEST VIRGINIA STUDY AREA

The County Medical Advisors and Administrative Policy Group are responsible for reviewing cases and setting the standing orders on paramedic protocol. The five physicians at West Virginia University are responsible for the real-time emergency consulting and care facility coordination.

There is only one advanced-care service in the area. This is located at West Virginia University Hospital which serves as the medical control center. In addition, two emergency-service hospitals and ten basic-care hospitals also serve the area. There are 25 individual EMS providers, including the county, private and volunteer ambulance services. In total, there are 90 EMS vehicles. Burn patients are usually transferred to hospitals in Pittsburgh, Pennsylvania.

The EMS communication system to date consists of a VHF dispatch system. There are plans to convert at least the point-to-point (hospital-to-hospital) communication system to UHF. One such link is now in operation between Sand Springs and the University Hospital. The planned UHF system will also connect the Fairmont, Clarksburg, Weston and Elkins hospitals. In addition, EMS squads operating within radio range of the hospitals with UHF base stations will also be able to access the system with the proper equipment. The existing and planned UHF systems are shown in Figure 3.9.

It can be seen on the communication network map (Figure 3.9) that Morgantown, the center of medical command in the area, is far from the geographic center of the district. This leads to long average-run distances for victims in serious condition and victims requiring emergency treatment during hours when nearer basic emergency service departments are not available. It is also noted that the transfer of complicated or serious problem cases and the transport of burn victims, to Pittsburgh, Pennsylvania adds further delays and thus further increases the need for telemetry.

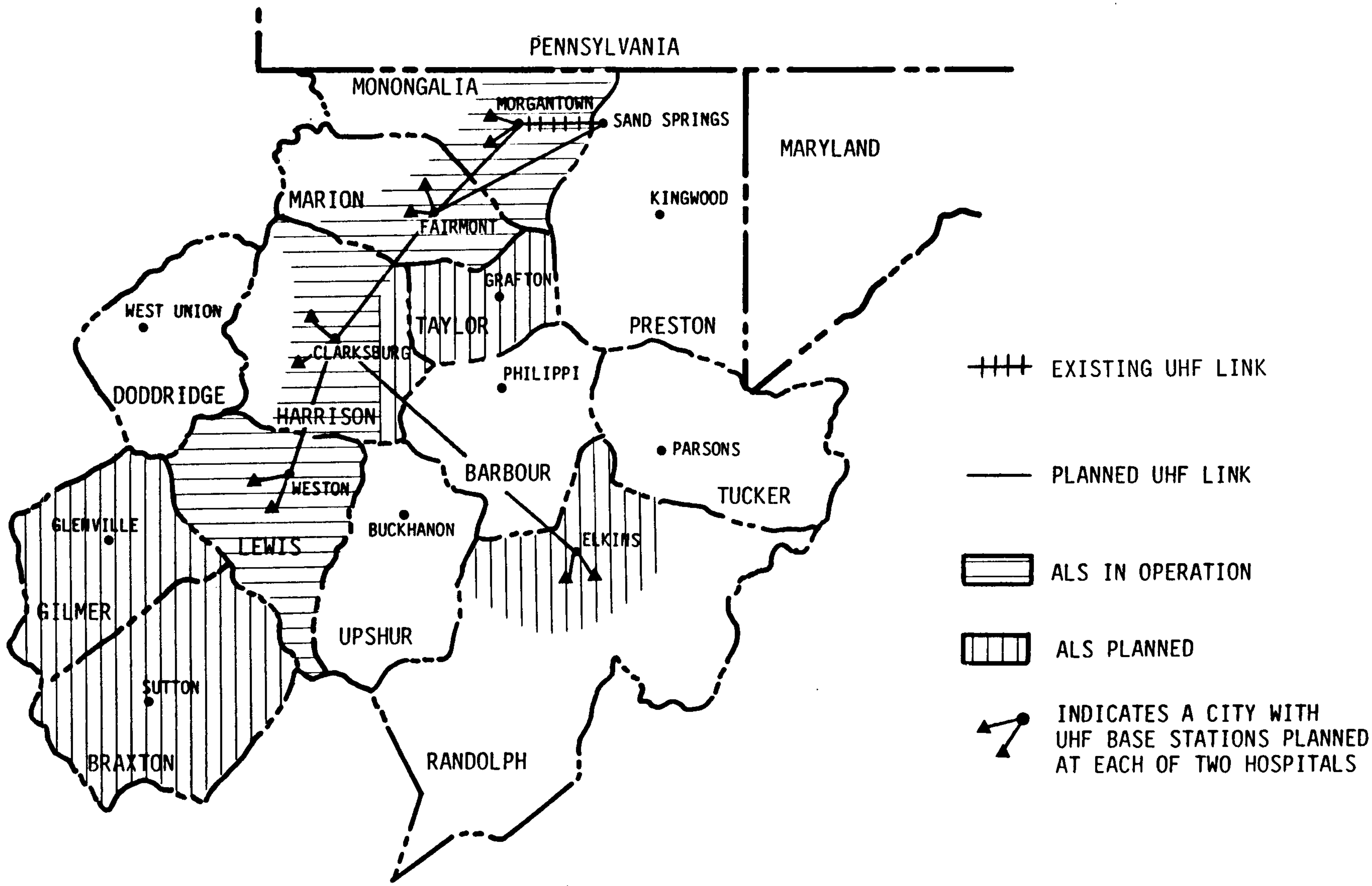


FIGURE 3.9 LOCATIONS OF PRESENT AND PLANNED COMMUNICATION NETWORKS FOR WEST VIRGINIA STUDY AREA

As depicted, the advanced life support (ALS) system is being instituted in the areas of highest population density first. The use of ALS in the region began in 1978, with the first areas commencing service in the first few months of the year and others added during the summer months. ALS systems are planned for Taylor, Gilmer, Braxton and part of Randolph Counties within a year or so.

Along with the ALS service, limited use of biomedical telemetry has been instituted. Since the system to send EKG and vital signs by radio is not available, these are being sent over private telephones when they are available at the scene. (Two-way voice contact for dispatch and care-facility coordination is handled by radio, either VHF or UHF, regardless of the presence of the telephone.) The district has met with only limited success in the use of telemetry by this method. Only about 50 percent of the victims are close enough to a telephone to use telemetry. Additional problems arise because the signal quality is poor, largely due to the length of the leads required to reach the telephone from the victim.

ECON conducted on-site interviews with administrators, doctors, communications experts and data control personnel in EMS Regions VI and VII during August 1978. The largest part of the information presented here was provided by the following individuals:

- Mr. Doug LaFanci, Project Administrator
- Mr. Mike Wuchner, Communications Expert
- Ms. Pat Gainor, Data Processing
- Dr. Walter H. Moran, Clinical Consultant.

Since the telemetry system that is planned for the West Virginia sample area has yet to be fully installed, there were no increased salvageability estimates available from this region. Thus, it was assumed that the figures obtained from the Texas sample area concerning the percent of trauma victims who could be salvaged without telemetry and the percent who could be saved with such a system were applicable to the West Virginia region.

Data available from West Virginia was largely based on data from a two-week sample period. This included statistics concerning time and distance traveled per emergency run. Furthermore, it was possible to estimate the number of emergency runs made by the West Virginia system. This was done by dividing the number of emergency runs listed in the sample by the total number of emergency room visits for the sample period.

This yielded the result that about 10.8 percent of all ER patients were being transported by the West Virginia EMS system. This was assumed to hold true for the entire year and was multiplied by the total number of annual emergency room visits (150,955, as obtained from DHEW) to yield the number of transports for the West Virginia sample area (16,326). This figure was then combined with the sample period percentage breakdown of transports by trauma type to yield annual EMS transports of the different types of trauma. Thus, while they were dependent upon the Trinity salvage rates, the figures from West Virginia reflect trauma and transport patterns unique to West Virginia.

Benefits of telemetry in West Virginia were relatively easy to derive because trauma transports were broken down (on a percentage basis) by type of trauma in the two-week sample. With the exception of emphysema (which was not listed in the sample), all of the trauma covered in Texas were also covered in West Virginia.

Of the 16,326 trauma victims transported in the West Virginia sample, 13.7 percent (2,237) were diagnosed as having cardiac problems. This was deflated by a factor of 0.21 to account for the fact that only 45 percent of all diseases of the heart are due to myocardial infarctions while 47 percent of all infarctions involve arrhythmia. Thus, 473 arrhythmia victims were estimated to have made use of the

West Virginia sample EMS system. Borrowing from the Texas sample, it was assumed that 30 percent of these (142) suffered "fatal" arrhythmias while the remainder suffered "nonfatal" arrhythmias. As before, additional telemetry-related salvages were 24 percent and 20 percent respectively. One hundred lives would be saved annually which translates to $2,400,000.

Auto accident victims accounted for 17.5 percent of all emergency transports (2,857). Shock and head and spinal injuries were assumed to account for 25 percent (714) and 15 percent (429) of the total, with the remainder being "minor injuries" for which telemetry would be of limited use. As in Texas, 24 percent of the shock victims (171) were assumed to be saved because of telemetry while 25 percent of the head and spinal injury victims (107) were assumed to be salvageable due to a telemetry system. In dollar terms, this translates to $7,695,000 and $4,815,000 respectively.

Poisoning victims accounted for only 0.4 percent of the emergency transports (65). An additional salvage rate of 25 percent would have accounted for ten lives or $400,000 saved.

Only 0.6 percent of the transports were for burn victims (98). Using the methodology used in the Texas user sample, it was estimated that the telemetry system would save 12 lives or $456,000 per year.

Table 3.16 presents the summary of the benefits from advanced communications in the West Virginia user sample. The fact that salvages are far higher in West Virginia than in Texas is not at all surprising. The resident population and emergency visits are both far higher than is the case in the Texas sample.

The traffic estimates for the West Virginia user sample are displayed in Table 3.17. Since the West Virginia system is not yet fully operational, it was

TABLE 3.16 BENEFITS FROM ADVANCED COMMUNICATIONS FOR THE WEST VIRGINIA STUDY AREA			
TRAUMA TYPE	NUMBER OF RUNS PER YEAR	LIVES SAVED ANNUALLY	ANNUAL BENEFITS ($1,000)
CARDIAC, ARRHYTHMIA	473	100	2,400
AUTO			
SHOCK	714	171	7,695
HEAD AND SPINAL	429	107	4,815
MEDICAL			
EMPHYSEMA	N/A	N/A	N/A
POISONING	65	10	400
BURNS	98	12	456
TOTAL	1,779	400	15,766

N/A = NOT AVAILABLE

TABLE 3.17 EMS COMMUNICATION-CHANNEL TIME REQUIREMENTS FOR THE WEST VIRGINIA STUDY AREA							
TRAUMA TYPE	NUMBER OF RUNS PER YEAR		AVERAGE CHANNEL TIME PER RUN (MIN)		PERCENT OF RUNS ON WEEKENDS*	AVERAGE CHANNEL TIME PER DAY ON WEEKDAYS (MIN)	AVERAGE CHANNEL TIME PER DAY ON WEEKENDS* (MIN)
	DISPATCH	TELEMETRY	DISPATCH	TELEMETRY			
CARDIAC, ARRHYTHMIAS	473	324	2.5	22.5	29	23.3	23.3
AUTO							
SHOCK	714	250	2.5	15	33	14.2	17.6
HEAD AND SPINAL	429	150	2.5	20	33	10.4	12.9
MEDICAL							
EMPHYSEMA	N/A	N/A					
POISONING	65	23	2.5	10	50	0.8	1.9
BURNS	98	34	2.5	17.5	50	1.6	4.0
TOTAL	1779	781				50.3	59.7

*FRIDAY AND SATURDAY (APPROXIMATELY 29 PERCENT OF THE WEEK).

impossible to obtain estimates concerning times required for dispatch and transmission of biomedical telemetry. As a result, it was necessary to employ figures obtained from the Texas sample area. These were chosen over the figures from Mississippi because the Trinity system in Texas has had greater experience in the use of telemetry and because it was able to offer data for a wider variety of sample types.

A major difference from the Texas study was the information concerning the percentage of runs made for motor vehicle accident victims on the weekend (the only area for which data is available from West Virginia). According to statistics provided by the West Virginia region, only 33 percent of all motor vehicle accidents occur on weekends (Friday and Saturday). Under the reasonable assumption that the number of injuries is proportional to the number of accidents, this leaves us far short of the assertion by the Trinity staff that half of their emergency runs for auto accident victims occur on weekends. There is no obvious reason for this, though sociological differences between the two areas as well as varying road qualities may provide some explanation.

Aside from this, the only significant cause for any difference in the traffic estimates is the far greater number of runs that occur in the West Virginia area.

To date, Regions VI and VII have spent $155,000 on stationary and mobile EMS equipment. In addition, a control console has been installed at West Virginia University at a cost of $50,000 for medical control of the entire system. Care must be taken in dealing with these figures, since they represent the sum total of equipment purchased by various organizations within the district over a period of years. The age of the equipment is not reflected here. It is also important to note that installation and maintenance are not explicit in the costs. It is conceivable that some of the equipment was purchased with a contract including installation and/or one year's maintenance, thus further reducing the confidence of the estimate.

Operating expenses for the present system are estimated by the experts at the region to be:

- $3,900 per year per hospital for telephone charges
- $275 per year for long-distance charges.

The UHF conversion costs were estimated in a preliminary study for the district by an outside consultant. The $256,000 is expected to cover equipment costs, installation, tower construction, an engineering study and (10 percent for) miscellaneous changes. The proposed scenario for construction of the system begins with the towers pictured previously and allows for expansion to provide comprehensive medical coverage as well as communications for other public service organizations, such as law enforcement.

Note that such a system would essentially eliminate the need in EMS for the hospital-to-hospital telephone lines and long-distance charges, except, of course, where the patient needs to be transferred out of the area to a hospital not connected to the district by UHF.

The costs of telemetry systems are based on the assumption of comprehensive coverage. When terrestrial systems are under consideration, it is further assumed that this coverage will be accomplished through the construction of 200-foot towers (for both UHF and public telephone). The case of existing towers will not be considered.

With the mountainous terrain of West Virginia, range becomes more uncertain. Mountains can either help or hinder transmission range. When one is concerned with comprehensive coverage rather than long-distance, point-to-point transmission, the chances are that the terrain will hinder transmission, thereby raising costs. Further, sub-optimal tower placement is a distinct possibility because of both technical and social (e.g., legal) constraints. For these reasons, a range of 10 to 20 miles is assumed for both UHF and public telephone transmissions.

In the case of a public telephone system, there is also the possibility that the hospitals' phone systems are inadequate; these costs are not included. Long-distance charges are taken to be a function of the number of runs and average distance traveled per run. It is also assumed that all segments of the EMS system are fully organized and cooperative.

Prices are taken from expert analyses given by the Trinity district (in the case of public telephone systems) and Motorola Corporation (for UHF).

The costs of constructing alternative communication systems for the West Virginia user sample were calculated using the methodology that was used in the Texas case study. Costs for the components are the same; that is, the Motorola cost figures were used for the UHF system and the Texas sample costs per unit were used in the public telephone system. A ten-year life for stationary equipment and a five-year life for mobile equipment were used. Capital costs for UHF include:

- Base stations at each hospital
- 200-foot towers
- Transmitter/antenna line
- Repeaters
- Portable mobile units (10-mile range)
- Portable units with vehicular repeaters (20-mile range).

Capital costs for public telephone include:

- Radio telephone switching stations (RTSS)
- 200-foot towers
- Mobile units (as above).

Annual operating costs for UHF include:

- Motorola maintenance agreement costs for radio equipment
- Tower maintenance.

Annual operating costs for public telephone include:

- RTSS maintenance
- Tower maintenance
- Long-distance charges
- Interconnection fee.

The estimated costs of constructing a UHF or a public telephone system for the West Virginia user sample area are given in Table 3.18. Satellite system costs are handled parametrically with respect to the average capital cost of ground stations and the connectivity charges to the user in Section 3.4 on the generalization of results.

3.3.3 The Mississippi Case Study

The Southeast Mississippi Air Ambulance District (SEMAAD) was established with the aid of grants from DOT and DHEW (local taxes now cover operating expenses) to provide emergency medical services to a seven-county area in the southeastern part of Mississippi. These seven counties: Covington, Forrest, Jefferson Davis, Lamar, Marion, Pearl River and Perry, are all nonmetropolitan areas with population densities that lie in the medium range of nonmetropolitan

TABLE 3.18 COSTS OF ALTERNATIVE COMMUNICATION SYSTEM FOR WEST VIRGINIA STUDY AREA

SYSTEM	CAPITAL COSTS		ANNUAL OPERATING COSTS		AVERAGE ANNUAL COST	
	20 MILE	10 MILE	20 MILE	10 MILE	20 MILE	10 MILE
UHF REPEATER	$ 1,370,900	$1,075,700	$ 41,520	$ 42,960	$ 277,610	$ 195,530
PUBLIC TELEPHONE	$ 1,306,000	$1,230,700	$ 36,022	$ 43,537	$ 258,722	$ 219,767

ALL SYSTEMS NOT STRICTLY COMPARABLE DUE TO CAPABILITY DIFFERENCES.
RANGES OF UHF AND RTSS COSTS DEPENDENT ON EXPECTED TOWER REQUIREMENTS.

counties, ranging from 13.2 to 133.1 persons per square mile. These figures are, however, higher than their counterparts in the Texas sample region, since 166,300 persons inhabit only a 3,829 square mile area. The terrain of this region, however, is not unlike that of the Texas sample, being primarily low rolling hills.

SEMAAD is currently in the process of adding an eighth county, Stone, to the region. Since it is not as yet fully incorporated into the region, it has not been included as a part of the sample area.

The operating center of the district is Forrest General Hospital in Hattiesburg. It is not, however, the geographical center of the region as seen in Figure 3.10. The district is fairly evenly covered by hospitals though the level of care varies considerably.

The seven-county region includes two major emergency service hospitals (both of which are located in Forrest county), three general emergency service hospitals and four basic emergency service hospitals. (An explanation of this categorization is given in Table 3.9.) In addition, there are ten EMS transportation providers in the area, which have 22 separate outlets. All of the above is under the blanket supervision of SEMAAD.

The communication system that serves the area consists of VHF dispatch. This is permitted to remain in the ambulances in which it has already been installed under a grandfather clause. The prohibition of further VHF systems has had little effect here, since most ambulances now have VHF. In addition, there is a UHF biomedical telemetry system that uses three towers. This system is still quite limited; comprehensive coverage will require from two to nine more towers (SEMAAD estimates three). The coverage now extends to a 20- to 30-mile range around Hattiesburg, which is where the two major emergency service hospitals are located.

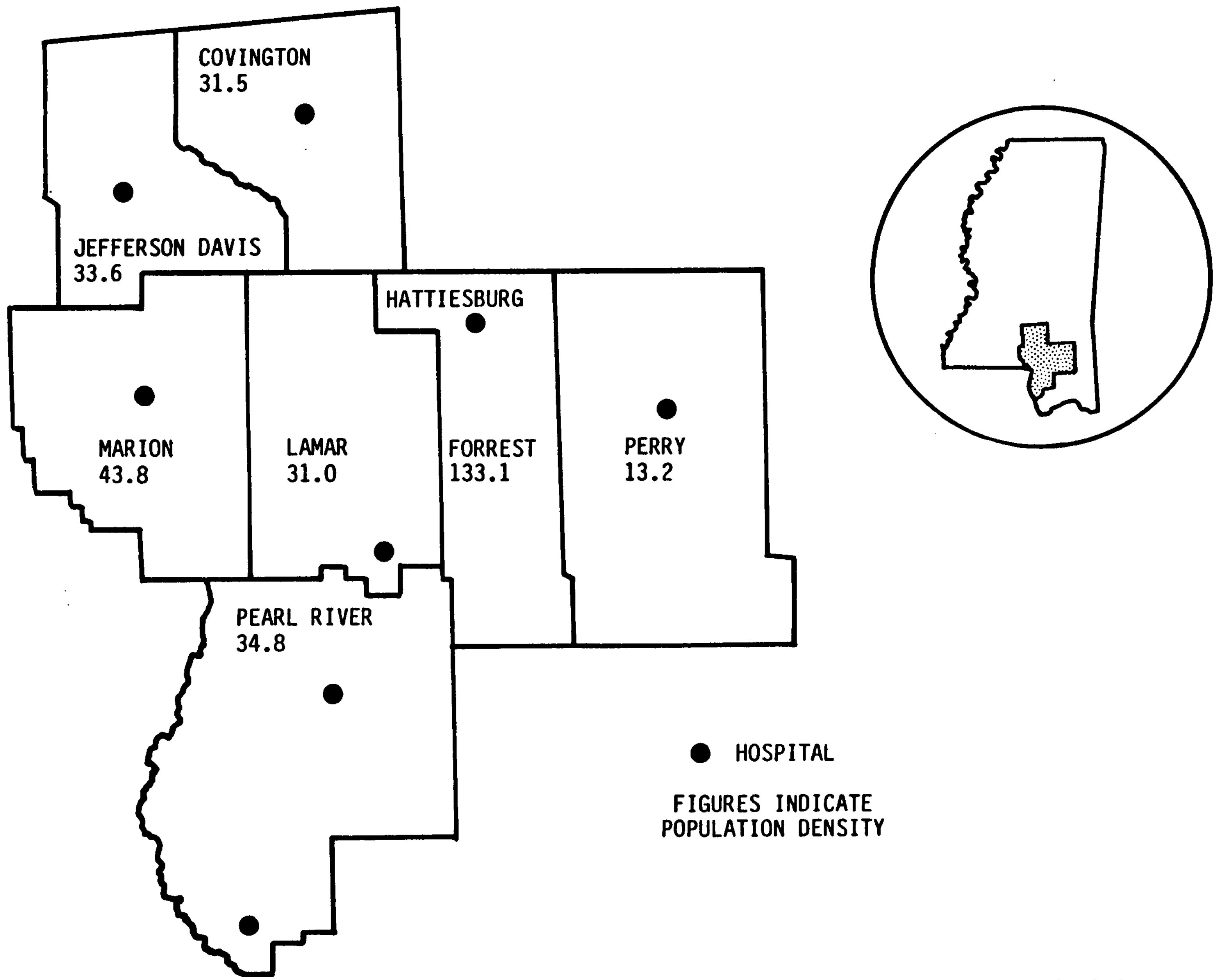


FIGURE 3.10 MAP SHOWING MISSISSIPPI COUNTIES SELECTED FOR EMS STUDY, WITH POPULATIONS

The hospital categorization for the area can be seen in Table 3.19. While all counties enjoy some emergency service, the level of the service often varies widely. Only Forrest County, with its two major emergency service hospitals, has fully-staffed emergency departments at all times. Jefferson Davis, Marion and Pearl River Counties have departments with full staffs on call, but much of the coverage remains at the basic level. Therefore, as in the Texas user sample, while all of the hospitals listed here receive some emergency patients, a major portion of those victims with severe or complicated traumas are transported, either directly or in transfers, to Hattiesburg. In addition, victims of accidents that occur during time periods when local emergency departments are not available will be transported to Forrest County. These instances, of course, raise the average distance traveled per emergency run and thus increase the need for telemetry.

Most of the data and estimates for the Mississippi case study were obtained during ECON's visit to SEMAAD during June 1978. The following individuals contributed information on the area:

- Dr. William C. Brundage, Director, Southern Regional Medical Consortium
- Dr. Cecil Burge, Project Director
- Dr. Richard H. Clark, Medical Director
- Dr. Frank Nagurney, University of Southern Mississippi
- Dr. Otto Salguero, University of Southern Mississippi.

It is important to note that as of September 1, 1978, SEMAAD received funding from a number of federal agencies to conduct a demonstration experiment for communications in EMS. Involved in this effort will be a substantial amount of work in data collection and evaluation. Work is being done to establish the benefits, medical effectiveness and cost effectiveness of alternative communication systems, including UHF, VHF, hardwire, public telephone, microwave and satellite systems.

TABLE 3.19 CATEGORIZATION OF HOSPITALS IN THE MISSISSIPPI STUDY AREA		
COUNTY	HOSPITAL	CATEGORIZATION OF EMERGENCY SERVICE
COVINGTON	COVINGTON COUNTY HOSPITAL	BASIC EMERGENCY SERVICE
FORREST	FORREST GENERAL HOSPITAL	MAJOR
	METHODIST	MAJOR
JEFFERSON DAVIS	JEFFERSON DAVIS COUNTY HOSPITAL	GENERAL
LAMAR	LUMBERTON CITIZENS HOSPITAL	BASIC
MARION	MARION COUNTY GENERAL HOSPITAL	GENERAL
PEARL RIVER	CROSBY MEMORIAL HOSPITAL	GENERAL
	PEARL RIVER COUNTY HOSPITAL	BASIC
PERRY	PERRY COUNTY HOSPITAL	BASIC

The economic benefit of satellite coverage to SEMAAD will be the forecasted change in the mortality rate as a function of telemetry coverage. The mortality statistics of the current 20-mile coverage system will be compared with the no-telemetry system used previously to give an indication of this change in mortality. For this study, only the mortality statistics on myocardial infarctions (MI) were available. The 150 deaths in the SEMAAD district last year due to MIs, which were taken to the Hattiesburg Medical Center, occurred even though 20-mile biomedical telemetry coverage was available. The statistic is misleading, though, since it is not known how many victims died en route to the hospital and how many were dead when the paramedics arrived. Under Mississippi law, and under the laws of almost all states, only a certified physician can sign a death certificate and legally declare the patient deceased. Therefore, even though the paramedics in many cases could do absolutely nothing, the patient had to be transported for legal purposes to the physicians in Hattiesburg.

Approximately 47 percent of the myocardial infarctions were due to arrhythmias (electrical failure of the heart). Patients with this condition can be saved if trained paramedics arrive in time with defibrillation equipment. Therefore, if 50 percent of the MIs were alive when paramedics arrived, and if 47 percent of these were arrhythmia victims, then comprehensive telemetry coverage could save 35 lives a year in the SEMAAD alone.

Increased salvageability estimates for other types of trauma were not available in this area. Therefore, only cardiac arrhythmia benefits are provided. Because in this user sample, as in the other areas, estimates of reduced morbidity were not available, benefit estimates of this type are not included. The summary of benefits of advanced communications to the Mississippi area is found in Table 3.20. In 1977 there were 1,600 trauma transports for nonmedical causes in the SEMAAD region, 1,200 of which occurred outside the Hattiesburg area. Of these, 40 percent (640) were for automobile-related injuries. If the percentages for shock and head and spinal injuries that were used in the Texas sample are used (25 percent and 15 percent respectively), it can be estimated that roughly 160 cases of severe shock and 96 cases of head and spinal injuries resulted from motor vehicle injuries.

The remaining 60 percent were dominated by victims of personal violence, with 80 to 90 percent of this type of incident occurring on weekends.

In addition to the above, there were 40 cases of neonatal trauma transports and 680 cardiac transports, 340 of which occurred within the area covered by telemetry.

TABLE 3.20 BENEFITS FROM ADVANCED COMMUNICATIONS FOR THE MISSISSIPPI STUDY AREA

TRAUMA TYPE	NUMBER OF RUNS PER YEAR	LIVES SAVED ANNUALLY	ANNUAL BENEFITS ($1,000)
CARDIAC, ARRHYTHMIA	680	35	840
AUTO			
SHOCK	160	N/A	N/A
HEAD AND SPINAL	96	N/A	N/A
TOTAL	936	35	840

N/A = NOT AVAILABLE

As mentioned previously, estimates for increases in salvageability due to advanced communications were not available for types of trauma other than cardiac arrhythmia in this sample area. Therefore, the results reflect only arrhythmia mortality benefits. It is expected that in the Mississippi user sample, 35 lives could be saved by using advanced communications in the emergency service provided to arrhythmia victims. Using the human capital methodology in its application to cardiac patients as described in the Texas user sample, one would expect the benefits to be approximately $840,000 per year. It is important to note that these benefits do include the benefits already captured in the area around Hattiesburg which presently uses advanced life support and telemetry of biomedical information.

The statistics related to traffic estimation and the estimates themselves are found in Tables 3.21 and 3.22. While dispatch requires only one-half duplex system, telemetry requires full duplex. This is due to the more complex demands made upon the telemetry system. These demands include two-way voice as well as the transmission of EKGs and other vital signs.

TABLE 3.21 NEED FOR EMS DISPATCH AND TELEMETRY FOR THE MISSISSIPPI STUDY AREA			
TRAUMA TYPE	DISPATCH TIME (MIN/CALL)	AVERAGE TELEMETRY TIME AT SITE (MIN)	PERCENT OF RUNS REQUIRING TELEMETRY AT SITE OR IN TRANSIT
CARDIAC, ARRHYTHMIA	5	15	100
AUTO			
SHOCK	5	15	15-20
HEAD AND SPINAL	5	15	15-20

TABLE 3.22 EMS COMMUNICATION-CHANNEL TIME REQUIREMENTS FOR THE MISSISSIPPI STUDY AREA

TRAUMA TYPE	NUMBER OF RUNS PER YEAR		AVERAGE CHANNEL TIME PER RUN (MIN)		PERCENT OF RUNS ON WEEKENDS*	AVERAGE CHANNEL TIME PER DAY ON WEEKDAYS (MIN)	AVERAGE CHANNEL TIME PER DAY ON WEEKENDS* (MIN)
	DISPATCH	TELEMETRY	DISPATCH	TELEMETRY			
CARDIAC, ARRHYTHMIAS	680	680	2.5	15	29	32.7	32.7
AUTO							
SHOCK	160	28	2.5	15	80	0.6	6.3
HEAD AND SPINAL	96	17	2.5	15	80	0.6	3.8

*FRIDAY AND SATURDAY (APPROXIMATELY 29 PERCENT OF THE WEEK).

Estimates for the length of time required per call were provided by the experts in SEMAAD. The philosophy of the use of telemetry in the area is (in contrast to the use seen in Texas) to use telemetry only when cardiac problems are suspected. This philosophy leads to lower rates of use in types of trauma other than in cases where cardiac problems are the primary reason for the emergency call. It is estimated that arrhythmias occur as a secondary problem or complication in 15 to 20 percent of all other severe trauma cases. This figure is particularly high in victims above 40 years of age.

The Mississippi traffic estimates are at variance with the Texas results in a number of ways. First, the percentage of transports for auto-related or other personal violence-related injuries is significantly higher. While a definitive explanation for this divergence is not available, the effects on the peak-to-average loading problem are obvious. A site like Mississippi, with 80 percent of the nonmedical calls coming on the weekend, would be forced to maintain a higher capacity level with respect to the average number of calls per day than would an area like West Virginia or Texas, where calls are more evenly spread over the entire week.

The second notable difference in the traffic estimates is seen in the average number of channel minutes required per run for telemetry. This is possibly due to a number of differences between the two systems (Texas and Mississippi user samples).

1. There seems to be a difference in the approach to or the philosophy of the use of telemetry. In the Texas area, telemetry of vital signs and EKG is used extensively as a diagnostic tool in many trauma types. Such information is valuable to the doctor who is recommending defibrillation, fluid replacement or drug therapies which have applications in cardiac, poisoning, burn, medical, auto-related and other types of traumas. The Mississippi sample seems to use telemetry only in suspected cardiac cases, whether the cardiac problem is the primary illness or a secondary complication.

2. Paramedic protocol may differ; that is, even if a Mississippi paramedic has physician approval, he may not be able to practice some of the fluid replacement or drug therapies available to the Texas paramedic.

3. Due to the average run distances and distributions of the population, need for telemetry en route to the hospital may be greater in Texas. Remember that in the Texas area, the advanced emergency facilities are not located within the sample area and, thus, the average run distances are extremely great.

4. The greater detail of data in the Texas site and estimation by the individuals involved with each may be at variance.

The system now in use in the SEMAAD district, consisting of three UHF towers and the related equipment for the area within 20 to 30 miles of Hattiesburg, cost $265,000 to construct. Unfortunately, operating and maintenance figures are unavailable.

The option of a public telephone system has been dismissed out of hand. The reason given is the fear that the hurricanes that frequently hit Mississippi would create sufficient havoc with phone lines to make a public telephone system impractical.

The cost of establishing a telecommunications network is based on the assumption that full telemetry coverage is to be accomplished by the construction of 200-foot towers. This presupposes that none of the existing educational television or forestry service towers are available for use by SEMAAD. Although some towers in Forrest County are available, the number is small enough that the assumption stands as reasonble.

In this region of low, rolling hills, the range of public telephone and UHF systems is assumed to be from 13 to 20 miles. Long-distance charges are assumed to be a function of both the number of runs and the average distance traveled per run. It is further assumed that all hospitals have telephone services that are capable of handling all calls.

Actual cost figures used for both of the terrestrial systems and the satellite-aided system areas are discussed in the related pages of the Texas case study.

In Table 3.23, the costs for a repeater UHF system are computed for both a 7-hospital and a 9-hospital system. There are actually nine hospitals within SEMAAD, each of which would require base station equipment, even though it does not accept all types of trauma victims or does not provide full-time (24 hours per day, seven days per week) service. However, according to the available national data published by the AHA, there are only seven emergency rooms in the area. The situation in regard to this system is analogous to the situation described for the Texas user sample. Cost estimates using both numbers of hospitals are presented in order to provide some insights into the relative conservatism of the generalized results. This distinction is of no relevance in a public telephone system, since its "base station" is the hospital's telephone system which is, by assumption, adequate. Interestingly enough, the public telephone system is consistently less expensive than the UHF system at the higher transmission range and consistently more expensive at the lower transmission range.

3.4 Generalization of Case Study Results

Results on benefits, traffic and costs were generalized from the three case studies to the nonmetropolitan areas of each of the fifty states. The magnitude of the values in each case was scaled in accordance with the terrain type, population density and existing EMS, as appropriate.

The geographic breakdown of the United States was carried out on a state-by-state basis, with the total United States figure representing the sum of all 50 states and the figures for the continental United States including only the contiguous 48 states. This distinction is an important one, since it demonstrates the unique position of Alaska. With the greatest nonmetropolitan area and the

TABLE 3.23 COSTS OF ALTERNATIVE COMMUNICATION SYSTEMS FOR THE MISSISSIPPI STUDY AREA

SYSTEM	CAPITAL COSTS (DOLLARS)		ANNUAL OPERATING COSTS (DOLLARS)		AVERAGE ANNUAL COST (DOLLARS)	
	20 MILE	13 MILE	20 MILE	13 MILE	20 MILE	13 MILE
UHF REPEATER 9 HOSPITALS	472,700	404,600	16,272	16,236	84,442	66,196
7 HOSPITALS	414,100	376,600	13,872	15,636	76,182	62,796
PUBLIC TELEPHONE/RTSS	356,830	447,900	10,803	14,892	67,519	69,318

ALL SYSTEMS NOT STRICTLY COMPARABLE DUE TO CAPABILITY DIFFERENCES.
RANGE OF UHF AND HARDWIRE COSTS DEPENDENT ON EXPECTED TOWER REQUIREMENTS.

smallest population of any of the 50 states, Alaska is marked by terrain that is as ruggedly mountainous as any other state. Thus, even ignoring the climatological problems peculiar to Alaska, this state is a perfect example of the need for satellite coverage, due to the huge capital expenditures that would have to be borne by so few people were towers to be erected for a terrestrial system.

The geographic breakdown given in Table 3.24 (with a more detailed breakdown in Appendix B) was performed with the help of two maps, one showing the location of Standard Metropolitan Statistical Areas (SMSAs) and the other depicting classes of land surface form. The two were compared to provide a picture of the land surfaces of the nonmetropolitan portions of each state. Three categories were designated: flat, hilly and mountainous. The fraction of each state that was in each particular category was then multiplied by the total land area of the state in question. The impact of a state like Alaska can be seen in the difference that occurs when only the "continental" United States is considered. (It should be borne in mind that only nonmetropolitan areas are considered; this considerably dilutes the impact of the more populated states.)

TABLE 3.24 GEOGRAPHIC BREAKDOWN OF U.S. NONMETROPOLITAN AREAS BY TYPES OF TERRAIN				
TERRAIN	NONMETROPOLITAN AREA OF U.S. (MI^2)	PERCENT OF TOTAL (50 STATES)	NONMETROPOLITAN AREA OF CONTINENTAL U.S. (MI^2)	PERCENT OF TOTAL (CONTINENTAL U.S.)
FLAT	419,071	14.6	419,071	16.9
HILLY	1,117,548	39.0	1,117,548	45.2
MOUNTAINOUS	1,329,489	46.4	934,218	37.8
TOTAL	2,866,108	100.0	2,470,837	100.0

Population density and emergency room "density" (actually, the number of square miles per emergency department) are of great importance in determining cost estimates for terrestrial as well as satellite systems. This is because these figures were used to estimate the number of mobile units and base stations that were required by each state. Statistical information on these densities is included in Appendix B. The population density of the nonmetropolitan portions of each state was determined by adding together the population of each of the nonmetropolitan counties for a particular state and then dividing this sum by the total area of the relevant counties.

Table 3.25 gives a breakdown of the states into those with low (10 persons per square mile or less), moderate (11 to 60) and high (61 or more) nonmetropolitan population densities. Interestingly enough, while the number of states breaks down evenly, with approximately one-quarter in each extreme and half the states in the middle, the area breakdown is heavily skewed towards those states with low population densities (mainly the western states). This further underlines the advantage that might be expected from satellite communications as the cost per capita for the construction of a terrestrial tower system would be staggering for those 12, thinly-populated states that contain 48.9 percent of the land area of the

TABLE 3.25 DEMOGRAPHIC BREAKDOWN OF U.S. NONMETROPOLITAN AREAS					
POPULATION DENSITY (PERSONS/MI^2)	NONMETROPOLITAN AREA OF U.S. (MI^2)	PERCENT OF TOTAL (50 STATES)	NUMBER OF STATES	NONMETROPOLITAN AREA OF CONTINENTAL U.S. (MI^2)	PERCENT OF TOTAL (CONTINENTAL U.S.)
10 OR FEWER	1,400,939	48.9	12	1,011,497	40.9
11 TO 60	1,278,460	44.6	25	1,272,631	51.5
61 OR MORE	186,709	6.5	13	186,709	7.6
TOTAL	2,866,108	100.0	50	2,470,837	100.0

United States. Of the sample areas in this study, however, none fall into this lowest group; Texas and Mississippi are in the middle range and West Virginia is in the high-density group. Again, the influence of Alaska is made evident by a comparison of the totals for the entire United States and for the continental United States only.

Average emergency room "density" was computed by counting the number of hospitals with emergency departments in nonmetropolitan counties. This number was then multiplied by 0.158, since an average of 15.8 percent of all nonmetropolitan emergency departments have full-time staff. The nonmetropolitan area of each state was then divided by the estimate thus obtained to yield a measure of emergency room "coverage" for each state. As might be expected, there is a strong relationship between population density and emergency department coverage, with more people per square mile implying more emergency departments per square mile.

In order to generalize the benefits of advanced communications from the case studies to the nonmetropolitan United States, the value of lives saved was computed according to the "human capital" methodology set forth in the Section 3.2.1, Benefits of Advanced Communications. The substantially lower figures for cardiac and emphysema victims reflect the advanced age of the average victims and--in the case of arrhythmia--the consistently shorter life expectancy. The value of each life saved was calculated as follows:

• Cardiac	$24,000
• Auto	$45,000
• Poison	$40,000
• Burn	$38,000
• Medical (Emphysema)	$20,000

It is most important to note that these figures are very conservative and that morbidity benefits are not included in the estimates. While all of the diseases listed are covered in the Texas sample area, West Virginia was unable to provide data concerning emphysema and Mississippi could only provide data concerning cardiac victims. Again, only mortality is considered because, while morbidity rates should improve with the introduction of telemetry, no systematic data is yet available. National benefits are based solely on benefits measured in the sample sites themselves. Thus, while nationwide cardiac benefits are based on all three samples, the benefits for emphysema stem solely from the Trinity area.

The generalization of benefits took place in three sections. The first of these involved cardiac benefits, the only trauma type in which improvement estimates exist for all three example regions. The auto accident, poisoning and burn victims were considered, since these were extrapolated from the West Virginia and Texas samples. Finally, emphysema was considered as it was derived from the Texas sample alone.

In computing the benefits for arrhythmia victims, national statistics and expert testimony were used to estimate that arrhythmias account for 47 percent of all myocardial infarctions which, in turn, make up 45 percent of all "diseases of the heart" (or 33 percent of all major cardiovascular diseases). In emphysema, salvages per capita for the Trinity district were multiplied by the total nonmetropolitan population of the United States. This yielded estimates for emphysema cases and telemetry-related salvages for the nonmetropolitan United States.

For the remaining trauma types, we had to make use of weighted averages from the appropriate case studies. These weights considered both population density and emergency department density. Intervals were constructed around the figures for each of the case study sites and states were then placed into one of the categories. This process was followed twice, once with all three case study regions and once with only Texas and West Virginia. Weights were assigned according to the total nonmetropolitan population in each state and the per capita figures were extrapolated to national levels. The dollar figures make use of the human capital value of lives saved for each of the trauma types. Total savings were found to be 59,445 lives and $2.3 billion. The benefits according to trauma type are presented in Table 3.26. These figures cannot be directly generalized to all forms of trauma despite the fact that these forms of trauma are estimated to make up 27.7 percent of all trauma. The reason is that salvage rates for the remaining trauma may differ from those traumas given in this study.

Table 3.27 presents the generalization of telemetry traffic to the entire nonmetropolitan United States. These figures are once again weighted averages of the figures obtained from the SEMAAD, Trinity and West Virginia case studies. The generalization followed the same pattern set forth for nationwide benefits from telemetry, with consideration taken of the population density and emergency department density. Recall that the emphysema figure is a direct extension of the Trinity region, while only cardiac traffic is derived from all three sample areas.

Since all emergency runs require dispatch, the first column generalizes the total runs made in each sample region for the relevant trauma type. This same

TABLE 3.26 GENERALIZED ESTIMATE OF ANNUAL BENEFITS TO UNITED STATES FROM ADVANCED EMS COMMUNICATIONS		
TRAUMA TYPE	LIVES SAVED PER YEAR	ANNUAL BENEFITS ($ MILLIONS)
CARDIAC, ARRHYTHMIA	13,296	319
AUTO		
SHOCK	26,356	1,186
HEAD AND SPINAL	14,996	675
POISONING	2,310	92
BURNS	1,059	40
MEDICAL		
EMPHYSEMA	1,428	29
TOTAL	59,445	2,341

TABLE 3.27 ESTIMATED EMS TELEMETRY TRAFFIC FOR NONMETROPOLITAN UNITED STATES			
TRAUMA TYPE	ESTIMATED DISPATCH	NUMBER OF CALLS/YEAR REQUIRING TELEMETRY (SITE AND/OR TRANSIT)	ESTIMATED CHANNEL TIME REQUIRED PER YEAR (MIN)
CARDIAC, ARRHYTHMIA	114,906	101,015	2,098,779
AUTO			
SHOCK	100,360	29,861	698,815
HEAD AND SPINAL	56,216	18,022	492,167
MEDICAL			
EMPHYSEMA	7,615	2,856	47,598
POISONING	14,049	4,948	84,602
BURNS	12,240	4,262	105,185
TOTAL	305,386	160,964	3,527,146

procedure was followed for the number of runs requiring telemetry in each of the sample areas.

To generalize the channel minutes required per year for each trauma type, it was first necessary to multiply the total number of runs by 2.5 (5 minutes of half-duplex transmission) to account for dispatch. To this was added the product of the number of runs requiring telemetry and the number of minutes required (of full duplex transmission). This was done for all relevant trauma types in each of the sample regions and the generalization was applied as above.

In order to generalize the cost results from the case studies to the nonmetropolitan United States, it is assumed that nonmetropolitan regions of a state will operate an EMS system as a unit. In the past, communication systems have been operated at a district level; however, recently a strong trend has developed to institute statewide control and uniformity in systems, data collection, etc. Implicit in this assumption are the other assumptions:

- Each state will enter and leave the market for satellite communications as a whole, based on overall cost effectiveness
- Each state will have a specified demand for ground terminals that is the sum of the number of emergency rooms and the estimated vehicle requirement of the nonmetropolitan regions of the particular state.

The number of vehicles required for the nonmetropolitan areas of each state was estimated from the number of ambulances per population unit in each of the sample sites. Within the three case study areas, there was an average of one ambulance for every 6,500 nonmetropolitan residents. The vehicle requirements per state are estimated accordingly.

For a description of the cost calculations, the reader is referred to Section 3.2.2, The Cost Model. Briefly, the assumptions that underly the cost calculations are:

- Each state operates an EMS system as a unit
- There is one base station per emergency room
- The number of mobile units estimated is based on population
- Stationary equipment has a 10-year life and mobile equipment a 5-year life (for all systems)
- 1977 dollars are used throughout
- Existing towers will not be used
- Cost sharing of new towers is considered
- The cost of powering towers is not considered
- Real estate costs for terrestrial systems are not included
- Motorola equipment and maintenance prices are used for UHF systems
- For public telephone, the network is in place; Texas cost estimates are used
- For satellite systems, a parametric approach to the average capital cost of ground terminals is used, a parametric approach to connectivity costs is used, maintenance per year is figured at 4 percent.

The expected costs, both total capital and average annual costs for each of the terrestrial communication systems, are shown in Table 3.28. The breakdown of these costs by state is shown in Table 3.29. The costs for the UHF and public telephone systems are range-dependent. That is, in the UHF system, it would cost $182.0 million to cover the total nonmetropolitan United States if the upper coverage range is realized (30 miles in flat terrain, 20 miles in hilly or mountainous areas): However, it would cost $241.7 million at the more conservative range estimates. Estimates for both the total nonmetropolitan United States and the continental United States are presented here, since cost estimates for a public telephone-based system in Alaska are, at least for the moment, of little value, as the Alaska public telephone network is not yet comprehensive. It is interesting to note that cost differences between the terrestrial systems are very small, and the

TABLE 3.28 ESTIMATED COSTS FOR ALTERNATIVE EMS COMMUNICATION SYSTEMS FOR THE NONMETROPOLITAN UNITED STATES*

SYSTEM	EXPECTED RANGE OF CAPITAL COSTS ($ MILLIONS)		EXPECTED RANGE OF TOTAL ANNUAL COSTS ($ MILLIONS)	
	LOWER MILEAGE RANGE	UPPER MILEAGE RANGE	LOWER MILEAGE RANGE	UPPER MILEAGE RANGE
UHF				
TOTAL UNITED STATES	182.0	241.7	35.0	39.3
CONTINENTAL UNITED STATES	173.6	211.0	33.8	35.0
PUBLIC TELEPHONE				
TOTAL UNITED STATES	180.3	340.6	36.0	52.5
CONTINENTAL UNITED STATES	165.4	283.0	34.0	45.0

*THE EMERGENCY MEDICAL SERVICE OWNS 100 PERCENT OF THE FIXED GROUND EQUIPMENT.

economic choice between the two (at least for the sum of all states) is dependent upon the radio coverage range attained.

Satellite system costs were determined for each state using the methodology described previously. In general terms, the annual cost is the annual capital cost for the required number of ER units, plus the annual capital cost for the mobile units, plus the cost of maintaining the system and the connectivity costs (that is, the charge per channel minute times the expected number of channel minutes required by the state for the year). The average capital cost for the ground terminals (hospital and mobile) is varied from $2,500 per unit to $50,000 per unit, and the cost per channel minute is varied over the range from $0.01 to $5.00. The resulting costs for the satellite system for each state are calculated at each combination of prices. These costs are then subtracted from the cost of the other systems (taken one at a time) to determine the cost effectiveness for each state at each combination of prices. The aggregate cost effectiveness for all of the states in which the system would be cost effective are presented in Tables 3.30 through 3.37. At each combination of prices, the aggregate cost effectiveness, the number

TABLE 3.29 EXPECTED AVERAGE ANNUAL COSTS OF ALTERNATIVE COMMUNICATION SYSTEMS BY STATE*

STATE	EXPECTED RANGE** UHF ($1,000)		EXPECTED RANGE** PUBLIC TELEPHONE ($1,000)	
	UPPER MILEAGE RANGE	LOWER MILEAGE RANGE	UPPER MILEAGE RANGE	LOWER MILEAGE RANGE
ALABAMA	792.2	602.5	826.1	709.5
ALASKA	1121.4	4220.0	1905.9	7439.4
ARIZONA	472.2	1071.3	612.5	1710.6
ARKANSAS	731.0	678.5	1160.2	888.8
CALIFORNIA	815.5	1084.3	784.4	1997.9
COLORADO	719.1	1041.8	570.8	1327.3
CONNECTICUT	176.6	95.9	150.2	84.3
DELAWARE	51.7	51.7	34.1	34.1
FLORIDA	412.6	412.6	290.1	220.6
GEORGIA	949.5	740.6	1084.7	889.7
HAWAII	100.3	106.4	87.8	56.9
IDAHO	555.4	1066.5	643.1	1670.7
ILLINOIS	1067.7	804.4	1109.3	1348.9
INDIANA	856.5	600.0	806.2	513.2
IOWA	1142.4	847.7	1270.1	1039.4
KANSAS	840.3	829.4	864.7	953.7
KENTUCKY	1014.2	837.6	807.1	639.9
LOUISIANA	644.4	540.3	642.4	558.0
MAINE	444.9	430.7	420.8	540.5
MARYLAND	237.1	171.1	216.6	298.7
MASSACHUSETTS	101.2	59.4	92.5	61.8
MICHIGAN	750.6	658.5	618.7	568.6
MINNESOTA	836.1	777.9	768.3	797.5
MISSISSIPPI	881.8	701.1	950.7	786.6
MISSOURI	868.2	764.0	784.3	820.3
MONTANA	692.8	1347.8	884.3	1936.9
NEBRASKA	1219.7	1290.0	632.6	858.0
NEVADA	318.8	1062.7	497.8	1839.4
NEW HAMPSHIRE	325.5	238.1	257.0	256.5
NEW JERSEY	146.8	112.2	215.9	96.6
NEW MEXICO	646.0	1195.1	846.4	1896.5
NEW YORK	1103.2	741.2	489.7	783.4
NORTH CAROLINA	1315.9	1607.9	1238.6	916.2
NORTH DAKOTA	428.5	521.5	472.6	691.3
OHIO	933.0	640.6	259.6	421.3
OKLAHOMA	775.5	714.8	942.5	941.8
OREGON	680.5	1183.0	757.6	1811.7
PENNSYLVANIA	1160.5	813.5	1019.4	2331.9
RHODE ISLAND	42.5	23.8	47.5	21.8
SOUTH CAROLINA	611.1	375.1	606.3	472.3
SOUTH DAKOTA	1165.6	880.3	1504.1	1211.3
TENNESSEE	933.1	691.6	985.4	825.3
TEXAS	1685.0	1825.2	1854.4	2396.3
UTAH	311.8	833.8	433.2	1406.8
VERMONT	259.8	218.3	229.0	436.2
VIRGINIA	857.4	616.3	891.9	975.2
WASHINGTON	602.7	728.8	1045.6	501.3
WEST VIRGINIA	644.0	519.8	542.1	599.0
WISCONSIN	1116.3	810.8	1200.1	972.4
WYOMING	451.6	1152.1	604.7	1915.3
TOTAL U.S.	35010.5	39338.5	35959.9	52471.6
CONTINENTAL U.S.	33788.8	35012.1	33966.2	44975.3

*100 PERCENT OWNERSHIP OF FIXED GROUND EQUIPMENT.

**REFER TO TABLE 3.4 FOR THE EXPECTED MILEAGE RANGE FOR EACH TYPE OF TERRAIN.

TABLE 3.30 COST EFFECTIVENESS OF SATELLITE SYSTEM COMMUNICATION COMPARED WITH UHF SYSTEM COMMUNICATIONS (I)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)											
	0.01		0.10		0.50		1.00		2.00		5.00	
2,500	34.11	50 / 1.000	32.75	50 / 1.000	26.73	50 / 1.000	19.39	45 / .927	12.67	19 / .244	4.96	4 / .015
5,000	27.96	50 / 1.000	26.60	50 / 1.000	20.62	47 / .989	15.29	26 / .388	11.11	17 / .219	4.86	4 / .015
10,000	16.28	36 / .649	15.52	31 / .495	13.21	23 / .326	11.4	17 / .219	9.25	12 / .105	4.66	4 / .015
15,000	11.65	19 / .244	11.35	17 / .219	10.19	15 / .154	9.29	13 / .114	7.90	10 / .086	4.51	3 / .008
20,000	9.32	13 / .114	9.17	12 / .104	8.59	10 / .086	7.95	10 / .086	6.75	8 / .058	4.42	2 / .004
50,000	5.37	5 / .024	5.33	5 / .024	5.22	4 / .015	5.11	4 / .015	4.88	4 / .015	4.06	2 / .004

*COST SAVINGS OF A SATELLITE SYSTEM OVER A UHF SYSTEM WHERE THE LOWER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 100 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.31 COST EFFECTIVENESS OF SATELLITE SYSTEM COMMUNICATION COMPARED WITH UHF SYSTEM COMMUNICATIONS (II)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)											
	0.01		0.10		0.50		1.00		2.00		5.00	
2,500	30.22	50 1.000	32.75	50 1.000	22.84	50 1.000	15.45	49 .978	3.85	19 .246	.78	2 .004
5,000	24.07	50 1.000	22.72	50 1.000	16.71	49 .978	9.35	49 .978	2.65	12 .101	.75	2 .004
10,000	11.78	50 1.000	10.42	50 1.000	4.77	38 .738	2.59	13 .116	1.62	6 .034	.71	1 .002
15,000	2.67	16 .199	2.45	14 .013	1.80	9 .070	1.54	5 .024	1.18	4 .015	.68	1 .002
20,000	1.6	6 .038	1.55	5 .024	1.40	5 .024	1.22	5 .024	1.08	2 .004	.64	1 .002
50,000	.85	2 .004	.84	2 .004	.82	2 .004	.78	2 .004	.72	2 .004	.44	1 .002

*COST SAVINGS OF A SATELLITE SYSTEM OVER A UHF SYSTEM WHERE THE UPPER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 100 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.32 COST EFFECTIVENESS OF SATELLITE SYSTEM COMMUNICATION COMPARED WITH UHF SYSTEM COMMUNICATIONS (III)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)																	
	0.01			0.10			0.50			1.00			2.00			5.00		
2,500	20.57	50	1.000	19.22	50	1.000	13.24	47	.970	7.59	27	.412	4.56	10	.080	2.00	2	.004
5,000	14.43	50	1.000	13.07	49	.994	8.06	32	.552	5.56	17	.224	3.90	10	.080	1.97	2	.004
10,000	5.88	19	.243	5.50	19	.243	4.57	13	.114	3.84	11	.094	3.06	5	.024	1.91	2	.004
15,000	3.90	9	.077	3.80	9	.077	3.41	7	.049	3.10	5	.024	2.74	5	.024	1.86	2	.004
20,000	3.22	7	.049	3.16	6	.038	2.96	5	.024	2.77	5	.024	2.50	4	.015	1.80	2	.004
50,000	2.07	2	.004	2.06	2	.004	2.04	2	.004	2.01	2	.004	1.94	2	.004	1.44	1	.002

*COST SAVINGS OF A SATELLITE SYSTEM OVER A UHF SYSTEM WHERE THE LOWER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 50 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.33 COST EFFECTIVENESS OF SATELLITE COMMUNICATION COMPARED WITH UHF SYSTEM COMMUNICATIONS (IV)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)																	
	0.01			0.10			0.50			1.00			2.00			5.00		
2,500	23.57	50	1.000	22.21	50	1.000	16.20	49	.978	8.84	49	.978	1.33	8	.054	.22	1	.002
5,000	17.42	50	1.000	16.06	50	1.000	10.09	49	.978	2.84	38	.728	.86	7	.042	.21	1	.002
10,000	5.13	50	1.000	3.78	49	.978	1.13	11	.091	.74	6	.034	.52	2	.004	.17	1	.002
15,000	.74	6	.038	.71	5	.024	.58	4	.015	.53	2	.004	.46	2	.004	.14	1	.002
20,000	.53	2	.004	.52	2	.004	.50	2	.004	.47	2	.004	.40	2	.004	.11	1	.002
50,000	.26	1	.002	.25	1	.002	.24	1	.002	.22	1	.002	.19	1	.002	.00	1	.002

*COST SAVINGS OF A SATELLITE SYSTEM OVER A UHF SYSTEM WHERE THE UPPER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 50 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.34 COST EFFECTIVENESS OF SATELLITE COMMUNICATION COMPARED WITH RTSS SYSTEM COMMUNICATIONS (I)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)																	
	0.01			0.10			0.50			1.00			2.00			5.00		
2,500	45.70	50	1.000	44.34	50	1.000	38.32	48	.992	30.95	43	.886	23.91	21	.279	11.63	6	.034
5,000	39.55	50	1.000	38.20	49	.999	32.23	47	.989	26.62	27	.419	22.12	18	.221	11.31	6	.034
10,000	27.91	37	.683	27.01	34	.614	24.58	24	.335	22.45	20	.257	19.23	16	.171	10.69	6	.034
15,000	22.91	22	.301	22.50	22	.301	21.05	18	.221	19.41	16	.171	17.30	13	.114	10.16	6	.024
20,000	19.65	18	.241	19.35	17	.219	18.34	15	.156	17.35	13	.114	15.85	11	.094	9.84	5	.024
50,000	12.11	7	.049	12.04	7	.049	11.75	7	.049	11.38	7	.049	10.80	5	.024	8.44	4	.015

*COST SAVINGS OF A SATELLITE SYSTEM OVER AN RTSS SYSTEM WHERE THE LOWER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 100 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.35 COST EFFECTIVENESS OF SATELLITE COMMUNICATION COMPARED WITH RTSS SYSTEM COMMUNICATIONS (II)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)																	
	0.01			0.10			0.50			1.00			2.00			5.00		
2,500	28.65	50	1.000	27.30	50	1.000	21.28	50	1.000	13.89	49	.978	5.58	15	.181	1.74	2	.004
5,000	22.51	50	1.000	21.15	50	1.000	15.15	49	.978	8.22	35	.657	4.54	12	.101	1.71	2	.004
10,000	10.21	50	1.000	8.87	46	.951	6.04	20	.276	4.54	14	.129	3.21	9	.065	1.66	2	.004
15,000	4.65	15	.177	4.41	15	.177	3.73	12	.104	3.08	9	.065	2.61	5	.024	1.60	2	.004
20,000	3.17	7	.049	3.10	7	.049	2.83	6	.038	2.64	5	.024	2.28	5	.024	1.54	2	.004
50,000	1.81	2	.004	1.80	2	.004	1.78	2	.004	1.75	2	.004	1.68	2	.004	1.23	1	.002

*COST SAVINGS OF A SATELLITE SYSTEM OVER AN RTSS SYSTEM WHERE THE UPPER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 100 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.36 COST EFFECTIVENESS OF SATELLITE COMMUNICATION COMPARED WITH RTSS SYSTEM COMMUNICATIONS (III)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)											
	0.01		0.10		0.50		1.00		2.00		5.00	
2,500	26.16	50 1.000	24.81	50 1.000	18.80	48 .992	13.05	26 .384	9.37	14 .139	4.06	4 .015
5,000	20.02	49 .999	18.67	48 .992	13.46	31 .505	11.00	18 .221	8.51	12 .104	4.00	3 .008
10,000	11.36	22 .301	10.97	19 .244	9.64	17 .219	8.55	13 .114	7.11	10 .086	3.91	2 .004
15,000	8.58	13 .114	8.43	13 .114	7.83	11 .094	7.15	10 .086	5.97	7 .045	3.85	2 .004
20,000	7.18	10 .086	7.06	10 .086	6.59	9 .077	6.09	7 .049	5.49	5 .024	3.79	2 .004
50,000	4.43	4 .015	4.41	4 .015	4.32	4 .015	4.21	4 .015	4.01	3 .008	3.44	2 .004

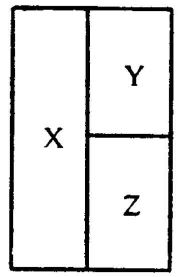
*COST SAVINGS OF A SATELLITE SYSTEM OVER AN RTSS SYSTEM WHERE THE LOWER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 50 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

TABLE 3.37 COST EFFECTIVENESS OF SATELLITE COMMUNICATION COMPARED WITH RTSS SYSTEM COMMUNICATIONS (IV)*

AVERAGE CAPITAL COST (FOR FIXED AND MOBILE UNITS, $)	CONNECTIVITY COST PER CHANNEL MINUTE ($)											
	0.01		0.10		0.50		1.00		2.00		5.00	
2,500	22.37	50 / 1.000	21.02	50 / 1.000	15.00	49 / .978	7.65	49 / .978	2.17	9 / .065	.61	1 / .002
5,000	16.22	50 / 1.000	14.87	50 / 1.000	8.90	49 / .978	3.16	21 / .286	1.65	8 / .054	.60	1 / .002
10,000	3.96	45 / .934	3.17	25 / .391	2.05	13 / .114	1.49	7 / .042	1.05	4 / .015	.57	1 / .002
15,000	1.49	7 / .049	1.43	6 / .038	1.26	5 / .024	1.08	5 / .024	.94	2 / .004	.53	1 / .002
20,000	1.11	5 / .024	1.08	4 / .015	1.00	3 / .008	.95	2 / .004	.88	2 / .004	.50	1 / .002
50,000	.65	2 / .004	.65	2 / .004	.63	1 / .002	.61	1 / .002	.58	1 / .002	.30	1 / .002

*COST SAVINGS OF A SATELLITE SYSTEM OVER AN RTSS SYSTEM WHERE THE UPPER MILEAGE LIMIT OF RADIO COVERAGE IS ATTAINED AND THE EMERGENCY MEDICAL SERVICE OWNS 50 PERCENT OF THE FIXED GROUND EQUIPMENT (MILLIONS OF DOLLARS PER YEAR).

of states for which the system is cost effective and the portion of the total nonmetropolitan traffic that would be served are given. At each combination of prices, this information is presented in the following format:



X is the number of dollars saved per year, in millions

Y is the number of states for which a satellite communication system will be cost effective at the given capital and connectivity costs

Z is the portion of total channel minutes required for EMS in the United States that is required by the Y states that would find the satellite system cost effective at the given cost levels.

Only the states for which the system is cost effective are included in the aggregation, because it is assumed that states that could purchase an equivalent system for less would do so.

Each of Tables 3.30 through 3.37 presents essentially a different case for the comparison of the satellite system. Tables 3.30 through 3.33 compare the satellite system to a UHF system, while the remainder compare the satellite system with an RTSS system. The four tables within each group present the various combinations of upper and lower limits to expected radio coverage ranges and the possibilities of the EMS provider owning either 100 percent or 50 percent of the fixed terrestrial equipment.

Examination of the eight tables shows that a comparison with the RTSS system where only the lower mileage limit is obtained and the EMS provider purchases 100 percent of the terrestrial equipment is the "best case" for the satellite, while a UHF system at the upper mileage limit and 50 percent ownership of the fixed equipment is the "worst case." Further, one can see from the tables that over the ranges of prices explored, the cost effectiveness is much more sensitive to the capital cost of the ground terminals than it is to the connectivity cost per channel minute.

If the satellite system was available at competitive prices, the potential market for such equipment would be relatively large. It is estimated that the potential demand for ground units to be used in nonmetropolitan hospitals would be about 2,500 units. It is believed that this estimate is extremely conservative because of the understatement of the number of emergency departments in national data that was discovered in two of the three case study areas. The demand for mobile units is expected to be about 8,800 units; however, the effects of the more cost-effective system have not been considered. In other words, if emergency medical service could be provided at a much lower cost, there would probably be an increase in the service provided, an increased number of ambulances and, thus, a greater demand for communications equipment.

It is also important to note patterns within the market. Because the terrestrial systems are relatively expensive for states with large areas of rugged terrain and/or low population densities, these are the states that would find the satellite system most cost effective (or in other words, cost effective at the highest prices). As a result, Delaware, Florida, Maryland and New Jersey are the first states to drop out of the market, while Alaska, Nevada, Utah and Wyoming are most likely to purchase such a system.

3.5 Conclusions and Recommendations

The major conclusions that can be drawn from the results of this study are (1) there are large benefits to be obtained from the installation of an advanced communication system in emergency medical services in the nonmetropolitan areas of the United States and (2) a satellite system could be cost effective over a wide range of capital equipment and connectivity costs.

The benefits of an advanced EMS communication system in the nonmetropolitan United States are expected to be about $2.3 billion annually or about 60,000 lives saved per year. These benefits are independent of the communication system type, but rather are dependent on the system capabilities. These benefits do include some benefits that have been captured by advanced communication systems already installed or planned and thus represent an upper limit for the types of trauma considered. On the other hand, they include benefits for the following trauma types only: Cardiac arrhythmias, shock, head and spinal injuries, emphysema, poisoning and burns, and are thus probably understated when other types of trauma are considered. These trauma types account for about 28 percent of the total number of emergency calls per year. However, because of the relatively high expected sensitivity of these problems to improved communications, it is not possible to extrapolate benefits from these results to all emergency calls.

The exact amount of these benefits that would be attributable to a satellite system is dependent upon how much of a terrestrial system is in place when an operational satellite system is implemented. For instance, today there are few systems with such capabilities available in the nonmetropolitan parts of the United States. If such a satellite system would be implemented within the next year, it would capture virtually all of the possible benefits. On the other hand, if the system is not available for twenty years, and another terrestrial system which supplies the same service is already in place, only the cost-effectiveness benefits would accrue to the satellite system. If the satellite system is available in the near future at reasonable prices, it may speed the installation of an advanced communication system in many areas. If so, it will capture the benefits for the additional years of service in those areas that, without the satellite, would have been lost by not having a communication system at all.

Since terrestrial systems are in place at the present time and will probably be expanded during the next few years, it is important that any future system that uses satellites consider the issue of compatibility with the existing ground system. While this issue is more technical than economic, it is likely that a satellite system that integrates existing terrestrial systems will be more acceptable (and possibly more beneficial) than one that does not. The entire issue of growth of existing terrestrial systems, and the integration of these systems with a new satellite system, should be the subject of further study.

The cost savings possible with a satellite system are a function of the capital costs of the ground terminals and the connectivity cost. Satellite-aided systems appear to be cost effective over a wide range of costs. Within the ranges of costs examined, the cost savings seem more sensitive to the capital costs of ground terminals than to the connectivity costs.

Because of the relative expense of terrestrial systems in such areas, the satellite-aided system appears to be most effective in states with large areas and mountainous terrain and/or low population densities. Flat, densely-populated states are more likely to find the system not cost effective at higher price levels for ground terminals and connectivity charges.

In order to verify the results, it is recommended that this study be reviewed both with the regions used in the user samples and with the national EMS staff at DHEW and DOT. It is hoped that, in doing so, support for both the benefit and cost numbers will be forthcoming, and thus outside approval and additional credibility will be gained.

In addition, there are several areas within the EMS area that require additional work. Largely because of DHEW and DOT grants, which require evaluation efforts, the data availability is changing rapidly. It is anticipated that, within the next year or so, much improved data on mortality will be available in the case study areas used in this report and in many other areas across the United States. In addition, morbidity data will be available in the Texas sample area and probably other areas. These data would allow improvement in the mortality benefit estimates and inclusion of an estimate of the impact of advanced communications on the morbidity of EMS patients. It is recommended that work continue with the EMS regions already contacted, and others, to use the improved data as well as situations of system change (that is, before and after the introduction of an advanced communication system) to expand and improve benefit estimates.

The second area which requires additional work is that of cost estimation. Work should be continued to improve the satellite-aided system cost estimates for both connectivity and capital components. Further work is needed to assure the terrestrial system estimate accuracy. Costs included in this study are of limited source derivation and may not in some cases include all the components of system costs. Examples of such a need are the estimation of remote power costs for terrestrial system, and of the current equipment and tower use possibilities.

It is also recommended that NASA, with the help of DHEW and one or more EMS districts, design an experiment that could be performed to measure the benefits of improved communications. Such an experiment should be performed during the mid-1980s to provide justification of the system itself and to demonstrate the potential viability of an operational satellite-aided EMS communications to the EMS providers who will eventually form the market for such a system.

4. FOREST FIRE FIGHTING APPLICATIONS

4.1 Introduction

Forest fires occur frequently throughout wide areas of the United States. In 1977 these fires caused an estimated $89 million in damages and burned almost half a million acres. Although fire damage and cost data are alarmingly incomplete, it is known that during 1977 there were over 14,000 fires in the National Forest protection area alone.* Fire suppression activities are becoming increasingly expensive and are estimated to cost on the order of $100 million annually.** In recent years, considerable advances have been made in fire fighting techniques. New technologies have been introduced, and modern scientific knowledge as well as operations research techniques now are used. However, the lack of good communications remains one of the major hindrances to effective fire suppression. In order to fully utilize modern fire fighting techniques, a great deal of information must be exchanged, both within the immediate area surrounding the fire and between the fire area and organizational centers located at some distance from the fire. Since many fires occur in remote areas, the requisite communications capacity is seldom available to fire fighters. Usually, terrestrial communication lines do not exist, and the rough, mountainous terrain in which many fires take place creates almost insuperable difficulties in the establishment of communications at short notice. Moreover, even where communication links, such as phone lines, are normally available, the fire can incapacitate them and the

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*Cumulative Forest Fire Record for National Forest Protection Area, January 1 through December 31, 1977, supplied by Bernie Erickson, U.S. Forest Service, Rosslyn, Virginia.

**Crosby, J., "A Guide to the Appraisal of Wildlife Damages, Benefits and Resource Values Protected," USDA Forest Service, RP No. NC-142, 1975.

existing capacity may be insufficient to cope with the demand of the fire fighting operations.

Satellite-aided mobile communications may be able to provide a solution to these fire fighting communication problems. In this study, a major application of mobile, satellite-aided communications to forest fire fighting is presented. The satellite-aided communication system then is compared, from an economic viewpoint, both with the terrestrial system currently in use and with a hypothetical improved terrestrial system under several alternative assumptions about the cost of the satellite system.

The terms "satellite-aided communication system" and "satellite system" are used throughout the text to refer to a radio communication network using satellite-borne radio repeater equipment that is capable of communicating with small, transportable earth terminals.

4.1.1 Overview of Fire Fighting Agencies

This section provides background material on the extent and ownership of U.S. forest land, as well as on the agencies involved in fire suppression. Such information is necessary in order to gain an overall picture of the organization of fire fighting activities in the United States.

In the United States, there are about 1.5 billion acres of land protected against fire hazard. About 48 percent of this land belongs to the federal government; the remaining 52 percent is state or private land. Unfortunately, no more detailed breakdown of the ownership of protected land is available. More detailed breakdowns do exist for ownership of commercial timberland. The federal government owns about 21 percent of the U.S. commercial timberland (the Forest Service, 18 percent; other federal agencies, 3 percent). State and locally-owned land accounts for another 6 percent. The bulk of commercial timberland is owned by the private sector (73 percent), while the remainder is owned by state, county or municipal governments.

However, the breakdown of commercial timberland ownership under-represents the role of state and federal agencies, especially the U.S. Forest Service, in fire protection. This is because most private landholders, including large lumber companies, such as Weyerhauser, contract the responsibility for fighting fires on their lands to state or federal fire fighting agencies. These agencies usually charge a fixed fee per acre for fire protection. The fee varies according to the type and the location of the land. (In rural Montana the fee is $0.16 per acre.)* In the event of a fire on or near their land, lumber companies may contribute both men and equipment to the fire suppression effort, but they seldom handle a fire, especially a large fire, on their own. Thus, the number of fire fighting agencies is much smaller than the widespread ownership of commercial timberland would suggest. The responsibility for fire protection is largely concentrated in the hands of a few state and federal agencies.

The division of responsibility among the various agencies is fairly simple. Most states give responsibility for protecting state and private lands within their boundaries to their state department of forestry. Federal agencies are responsible for fighting fires on federal lands. In the case of large fires (1,000 acres or more), the state fire fighting resources are often not adequate, and the U.S. Forest Service provides assistance in men and materials. In addition, if a pocket of state land lies within a larger area of federal land, the federal agency will usually be responsible for fire protection on the state land and vice versa.

*Dick Sandman, Montana State Fire Chief, Missoula, Montana.

The most important federal agencies involved in fire suppression are the United States Forest Service (USFS), the Bureau of Land Management (BLM), the Bureau of Indian Affairs (BIA) and the National Park Service. Each of these agencies administers large sections of land throughout the United States. The National Weather Service, which closely monitors fire weather, is also involved in fire suppression. The activities of all these federal agencies are coordinated, and often supplemented, by the Boise Interagency Fire Center (BIFC) located in Boise, Idaho. BIFC serves as a nationwide store for fire fighting equipment, which it makes available to the regions when necessary. In addition, it is a center of fire expertise for the nation as a whole.

Some knowledge of the internal structure of the federal agencies involved in fire suppression is also useful for understanding the organization of fire fighting. The largest of these agencies is the Forest Service, which administers the national forests throughout the country and has primary responsibility for protecting national forest land. It also enters into agreements with other federal and state agencies to protect land outside of the national forests. The Forest Service is organized into ten regions, each responsible for a particular area of the United States (see Table 4.1 and Figure 4.1). Each national forest has a fire team capable of fighting small fires and mounting an initial attack on larger fires. When the fire situation exceeds the capacity of an individual forest team, the regional office for the area supplements or takes over the suppression efforts. The regional office can call in men and equipment from other national forests in its region or, if necessary, enlist the support of BIFC and the other regions or of other federal and state agencies. The other federal agencies' organizations are similar to the Forest Service. They have main offices in Washington, DC and at Boise (as parts of BIFC), and have regional offices throughout the country. The BLM manages 456 million

TABLE 4.1 DIVISION OF THE U.S. FOREST SERVICE REGIONS	
REGION	STATES
1	MONTANA, NORTH DAKOTA
2	WYOMING, SOUTH DAKOTA, COLORADO, NEBRASKA, KANSAS
3	ARIZONA, NEW MEXICO
4	IDAHO, NEVADA, UTAH
5	CALIFORNIA
6	WASHINGTON, OREGON
7	HAWAII
8	OKLAHOMA, TEXAS, ARKANSAS, LOUISIANA, MISSISSIPPI, TENNESSEE, KENTUCKY, ALABAMA, VIRGINIA, NORTH CAROLINA, SOUTH CAROLINA, GEORGIA, FLORIDA
9	MINNESOTA, IOWA, MISSOURI, WISCONSIN, ILLINOIS, MICHIGAN, INDIANA, OHIO, NEW YORK, PENNSYLVANIA, WEST VIRGINIA, MARYLAND, DELAWARE, NEW JERSEY, RHODE ISLAND, CONNECTICUT, MASSACHUSETTS, VERMONT, NEW HAMPSHIRE, MAINE

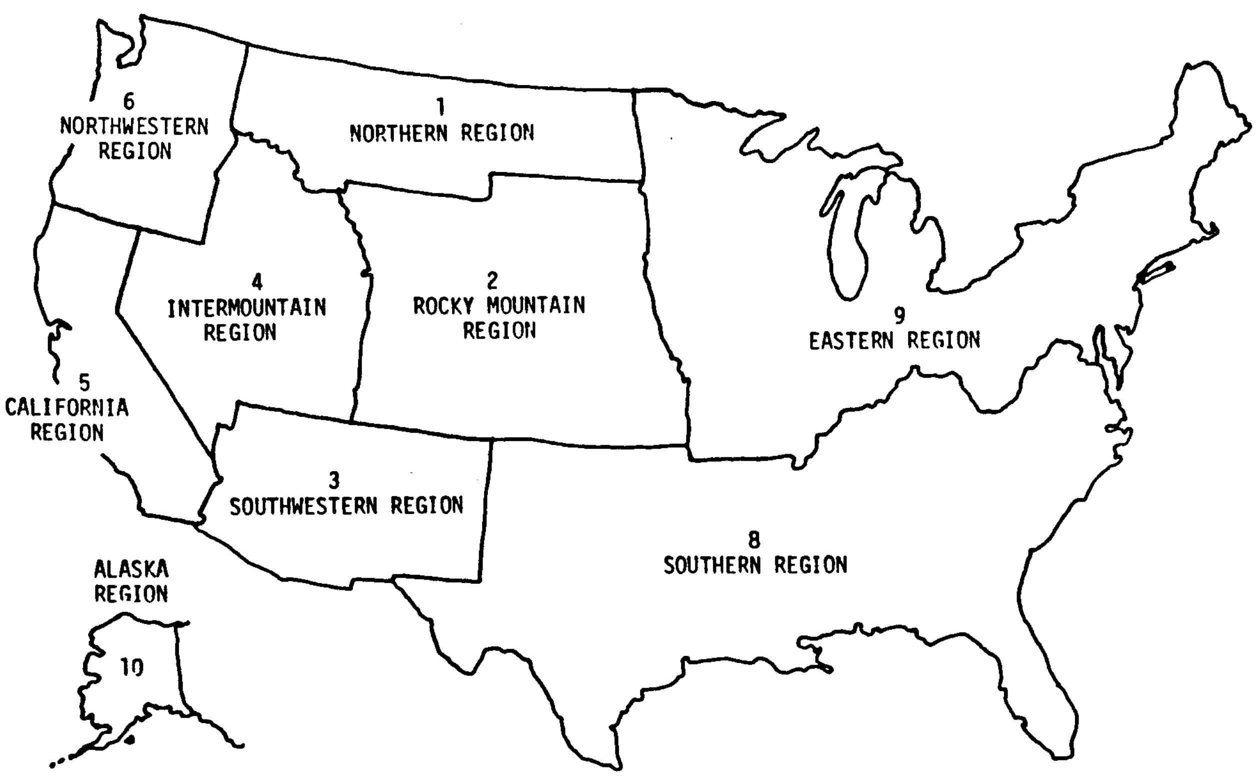


FIGURE 4.1 U.S. FOREST SERVICE REGIONS

acres of national resource land located mainly in Alaska and in the western states. The BIA is trustee for Indian lands throughout the country, and National Park Service administers the national park system.

4.1.2 Present-Day Fire Suppression and Communications

An overview of present-day fire fighting strategy, with an emphasis on communications requirements and present-day communications capacity, is presented in this section. The discussion focuses mainly on the fighting of large fires, because communication plays an extremely important role in these fires; in smaller fires, its role is relatively minor. Fire fighting procedures of the Forest Service are described here; however, the procedures of other agencies are essentially similar.

When a fire is discovered on national forest land, that forest's fire team is immediately sent to the fire. During this period of initial attack on the fire, the team uses the regular forest communications network. This usually is a system consisting of one or two radio channels that are used in the daily operations of forest personnel. If it becomes evident that the fire is going to be large, a special group, called a large fire team, takes over the suppression efforts. Special communications equipment is flown into the fire area from a BIFC fire cache located in the region or in Boise.

Since fighting a large fire usually involves a tight organization and a large number of men and supplies, good communication is essential if the suppression efforts are to be effective. In order to understand the communication needs for a large fire, it is necessary to have some understanding of the large fire fighting organization. Most large fires are fought in a manner similar to the three-Division fire to be described. Though it may not conform precisely, on the whole, the three-Division model provides a convenient framework for describing large fire communication needs.

In a three-Division fire, the fire fighting efforts are coordinated by the fire boss and his deputy, the line boss, operating out of a fire camp located approximately 1/4 mile from the fire line, as shown in Figure 4.2. Also, as shown in Figure 4.2, the fire line is sectioned into three divisions (A, B and C), each representing beyween 150 and 200 men directed by a division boss. Each division is, in turn, divided into up to three sectors (1, 2 and 3) with their sector bosses. Under each sector boss, there are three crew bosses, each responsible for several squads of about seven men each. In addition to this ground network, there is an air organization for each fire, directed by an air boss who is in contact with the fire camp and with an air base from which aircraft used in fighting the fire operate. The fire camp is linked to the general fire headquarters (GHQ in Figure 4.2), which may be located several miles away from the fire, usually in a permanent facility with easy access to phone communications and data processing equipment. The general headquarters often coordinates the fire fighting activities for several fires in the area and is in contact with BIFC and other sources of men and supplies.

A three-Division fire uses four separate communications networks: air, command, tactical and logistics. The air network links the air boss, tankers, helicopters, air base and fire camp. The tactical network provides communications along the fire line and between the fire line and the fire camp. It serves sector bosses, crew bosses and lower ranking personnel. The command network serves the division and higher ranking bosses along the fire line and in the fire camp. The logistics network is used for the strategic purpose of ordering men and supplies, and for transmitting data to the outside to be processed and used to design an effective fire fighting strategy. The logistic network links the fire camp, the

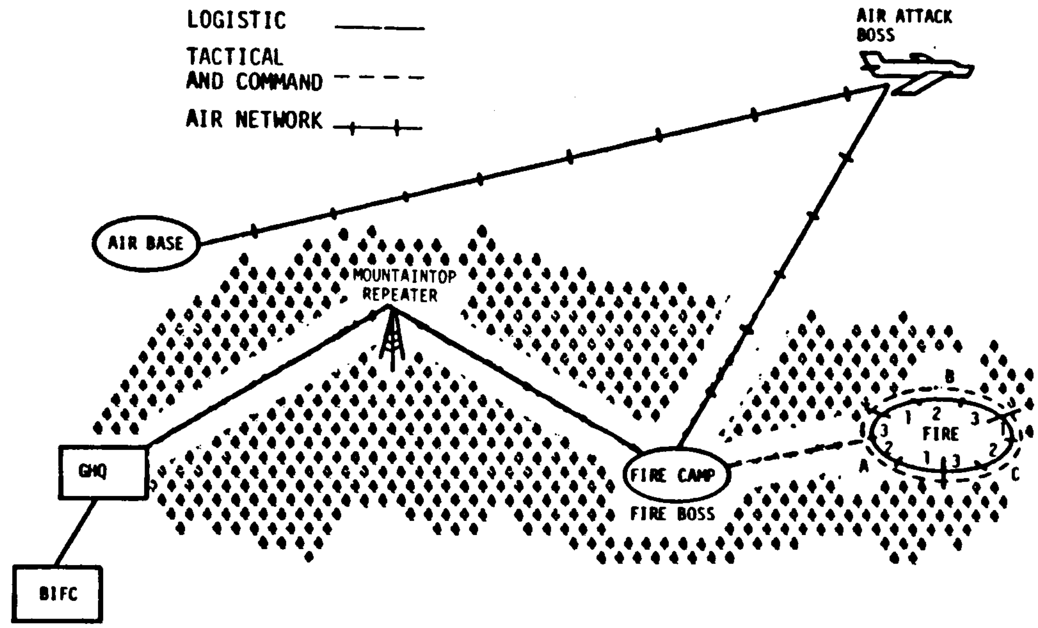


FIGURE 4.2 THREE-DIVISION, TERRESTRIAL, LARGE-FIRE COMMUNICATIONS NETWORK

general headquarters and BIFC. Between BIFC and the general headquarters, telephone communication is used. Telephone lines are also installed, whenever possible, between the fire camp and the general headquarters. When this is not possible, radio communication is used. At present, one duplex VHF radio channel serves the logistic need. BIFC is planning to phase in new equipment, however, which will use UHF frequencies. It will have the added advantage of allowing the use of either facsimile or voice channels, although it will still be possible to use only one channel at a time.

BIFC owns 15 tactical and nine logistics communication systems, which it makes available for use in large fires. It is planning to increase the number of logistics communication systems with the new equipment mentioned above. The BIFC equipment is typical of what is presently used in this country for fighting large fires.

BIFC's tactical systems are used for both the tactical and the command networks just described. Each tactical system contains 13 kits which consist of:

- Three-Division kits (one for each division), each containing 15 personal portable radios and two pack sets. These kits are used by fire-line personnel
- One kit containing necessary materials for setting up a repeater to connect the fire camp and the fire line
- One kit containing eight personal portable radios and four pack sets for use in the fire camp
- One kit containing everything necessary to set up a public address system in the fire camp
- Three kits containing one pack set each for setting up base station units up to 1,500 feet from the fire camp
- Two accessory kits
- One "tactical special" kit, containing ten personal portable radios for use wherever needed
- One kit containing a VHF AM aircraft base radio station.

All radios in each of the 15 tactical systems have the same number of channels (either five, six or eight), depending on the age of the system. New systems will all have eight channels.

The BIFC logistic systems contain three base stations and one repeater unit, and have a one-channel capacity. They are used for the logistics network.

In 1972, a U.S. Forest Service telecommunications study estimated the average purchase cost for radios in 1971. These costs are shown here, inflated by the consumer price index to 1977 levels:

Radio Item	Average Purchase Cost (1977 $)
Mobile	$544
Portable, Light	688
Portable, Heavy	1,121
Base Station	1,289
Base Station, Table Top	921
Remote Control Console	374
Radio Link, Base	1,807
Radio Link, Repeater	4,111
Repeater, AC	1,754
Repeater, Battery	2,855

Most fire experts agree that present-day logistics communication systems are inadequate to meet the communication needs of large fires, but that available equipment adequately covers the needs of the tactical, command and air networks. The one-channel capacity of present and planned logistic systems is considered insufficient by virtually all experts. The BIFC believes that at least six dedicated circuits (eight in Southern California) are needed to provide adequate communications between the fire camp and the general headquarters.* These include (1) three voice-grade circuits to be shared by the Fire Communications Center, Fire Information Officer and other work centers in the fire camp, as the particular fire situation dictates; (2) two facsimile circuits, one dedicated to Service/Supply, the other to be shared by fire-camp work centers, and; (3) one computer-grade circuit to be used for timekeeping, resource coordination, data on weather conditions, etc. This increased capacity would allow more and better information about the fire situation and the needs of the fire team to be transmitted and, hence, enable the general headquarters to use fire fighting resources more efficiently and to devise better fire fighting strategies. This is particularly true for the increased facsimile (hard-copy) transmission capability. If all logistics

*Based on an interview with BIFC personnel on July 14, 1978 in Boise, Idaho. Present at the meeting were Don Velasquez, Chief of Fire Communications USFS-BIFC, Les Helms, Electronic Technician USFS and John Warren, Electronic Engineer USFS.

orders could be made and confirmed on hard copy transmitted between the fire camp and general headquarters, numerous errors and sources of inefficiency could be avoided, and logistics coordination would be greatly facilitated. In addition to lack of capacity, another major problem of present-day logistics systems is the amount of time they take to set up. When radio communication is used, it is necessary to place repeaters on mountain tops. This can take anywhere from two to 12 hours from the arrival of the communications equipment at the fire camp, depending on how difficult it is to get the repeater to the mountain top and how long it takes to place it in the correct position. This delay can severely hamper the fire suppression efforts in the first stages of the fire. Until the repeater is in place, logistics communications is carried out by radio-to-radio relays or by messenger. Thus, requests for men and equipment do not reach the general headquarters as fast as they should, and the messages received are often inaccurate or insufficiently detailed. In later stages of the fire, when it is perceived that the fire is going to last some time, telephone lines or microwave systems are often ordered to supplement the logistics communication by radio. These can take as long as two or three days to install, during which time logistics communication is limited to one radio channel of the BIFC system. Here again the efficiency of the fire fighting efforts is hampered by lack of adequate logistics communication. In addition to these problems, present-day communication systems lead to nonoptimal fire camp placement, as the fire camp must be located next to existing sources of communication (for instance, phone lines), rather than in the best place from which to fight the fire.

In summation, the communication systems currently used for logistics communication in large fire suppression efforts are inadequate to meet the needs of the large fire fighting organization. Problems with the systems fall into two major categories: (1) those arising from the insufficient capacity of these systems and (2) those due to the length of time required to install them. If logistics communication could be improved sufficiently to overcome these problems, many of the costly inefficiencies which hamper large-fire suppression efforts could be avoided.

Communications via a satellite-borne radio repeater from a small, transportable earth terminal located in the fire camp to a base station in the general headquarters could greatly facilitate large-fire logistics communication (see Figure 4.3). If the transportable terminals were prepositioned in the BIFC fire cache locations, they could be brought to the fire camp as quickly as existing BIFC communication systems are now. The system could be operable within an hour after arrival of the terminal at the fire camp. This would be several hours earlier

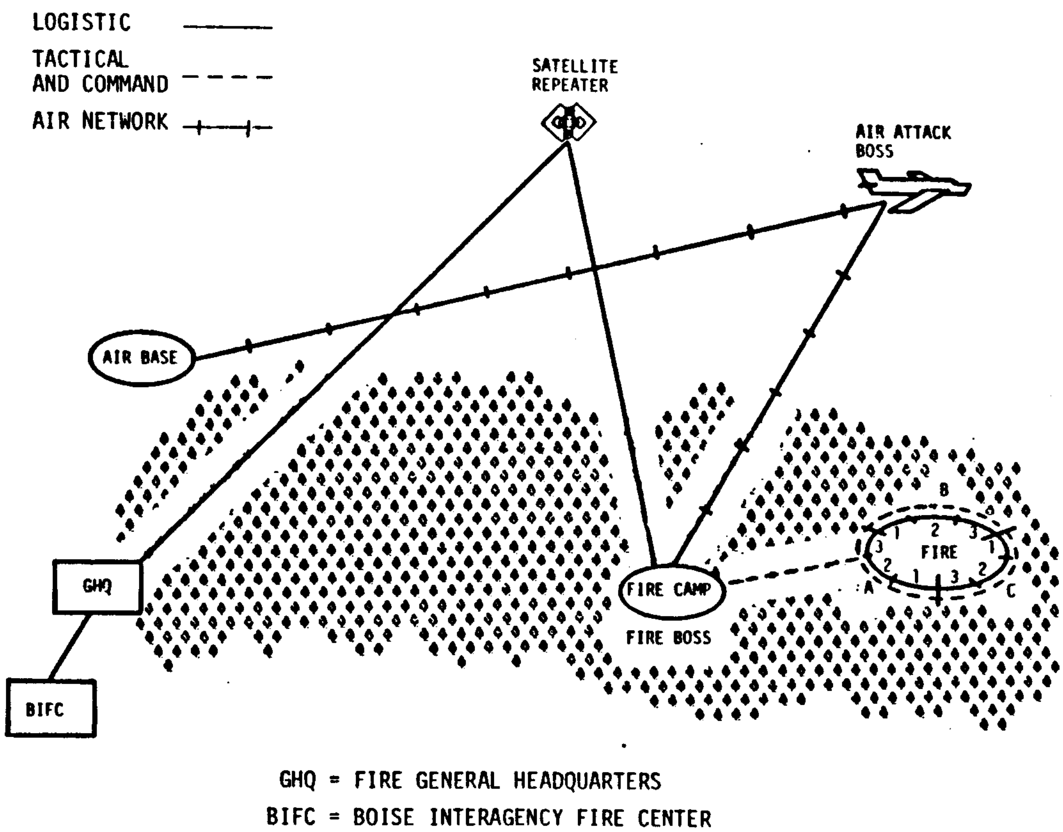


FIGURE 4.3 SATELLITE-AIDED LARGE-FIRE COMMUNICATIONS NETWORK

than a repeater could be correctly positioned on a mountain top (to allow existing systems to begin operation). Thus, the satellite system would guarantee the vital communications link between the fire camp and the general headquarters during the first few hours of the fire sooner than any terrestrial system presently used. Furthermore, the satellite repeater could provide all six channels required for logistics communications, greatly increasing the usual communications capacity and avoiding the further delays in installing phone lines or microwave systems. This additional capacity would allow rapid facsimile transmission, thereby increasing the efficiency of logistics operations. The satellite system would also free fire-camp locations from the constraints imposed by the need to be near phone lines, and so would allow more nearly-optimal fire camp placement.

Thus, satellite communications and transportable earth terminals have the potential to overcome the major problems of today's communication systems.

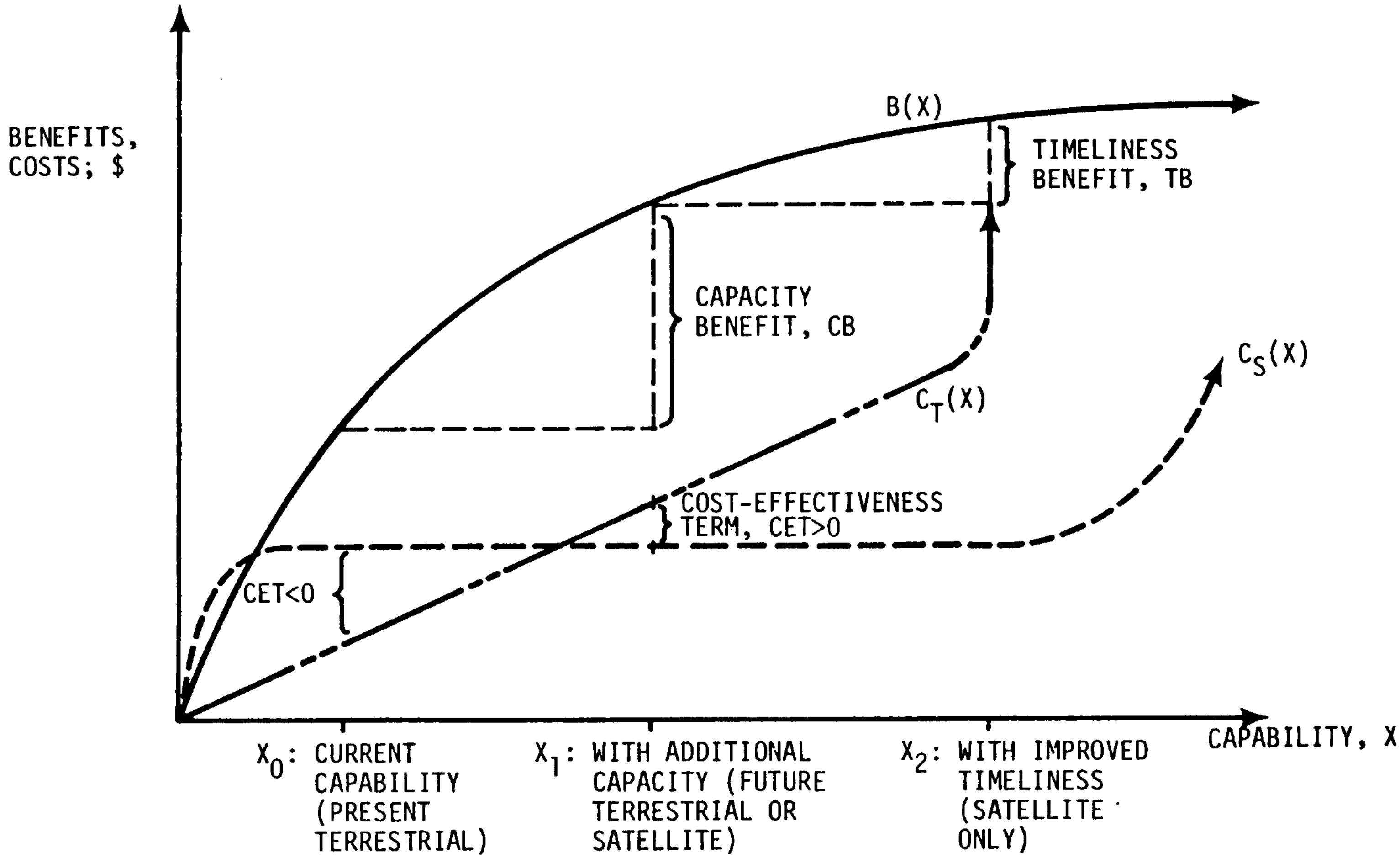
Alternatively, some of the problems of today's communication systems could be overcome by improved terrestrial communications. It is possible to increase the capacity of terrestrial systems sufficiently to avoid problems resulting from inadequate capacity, although it probably would not be possible to decrease the delays in installation. Therefore, the costs and benefits of satellite communications relative to both the existing terrestrial systems and an improved terrestrial system with increased capacity should be examined.

4.2 Benefit and Cost Methodology

The methodology used to compute the benefits of a satellite-aided communication system in the forestry application is explained in this section. The specific forest fire application examined is the use of transportable earth stations with six- to eight-channel capacity for logistics communications between the fire camp and the general headquarters as shown in Figure 4.3 (one station is located in the fire camp, another in the general headquarters). Only logistics communications for large fires (1,000 acres or more) were studied. Furthermore, only those large fires which lasted longer than 20 hours were considered. Since it is difficult to know when a satellite-aided communication system might become effective, the satellite system was compared both to the current terrestrial system (characterized by one full duplex channel capacity and delays of six to 18 hours in repeater deployment time) and to an improved terrestrial system with six-channel capacity, but with similar delays in repeater deployment, which might be in place when the satellite-aided system becomes operational. Thus the methodology developed for this study attempted to account for the evolutionary nature of communication systems.

Figure 4.4 is an illustration of the benefits and costs of satellite-aided mobile communications as a function of capability. This figure explains the benefit-cost methodology employed in this study. The benefit function B(X) expresses dollar benefits as a function of capability. Certain capabilities can be provided by both the satellite and terrestrial systems, while other capabilities can only be provided by the satellite. For example, the capability benefit shown in Figure 4.4 is the incremental benefit that could be realized today if some communication system, whether satellite of terrestrial, could offer a six-channel voice capacity deployed within six to 18 hours. The benefit is incremental in the sense that it is above and beyond the benefits produced by the current system. The deployment time of six to 18 hours is the current deployment time.

On the other hand, the timeliness benefit shown in Figure 4.4 is an incremental benefit over and above the sum of current and capacity benefits. This benefit can be provided by the satellite-aided system (since it is assumed that the satellite system could be implemented in less than six hours), but cannot be provided by



CAPACITY	1-CHANNEL VOICE	6-CHANNEL VOICE	6-CHANNEL VOICE
TIMELINESS	6-18 HOURS	6-18 HOURS	<6 HOURS

FIGURE 4.4 ILLUSTRATION OF TECHNOLOGY, COSTS AND BENEFITS OF FORESTRY APPLICATION

terrestrial systems. With this type of framework established, it is clear that if the satellite-aided system is implemented after an improved terrestrial system with six-channel voice capability is in place, the satellite-aided system could claim only the timeliness benefits. If, on the other hand, only the current system is in place when the satellite is introduced, both the capacity and timeliness benefits could be claimed (CB + TB).

Returning to the capacity benefit (for capability equal to X_1), it remains to be determined which communication system, satellite or terrestrial, is the most competitive. This issue is settled by a cost-effectiveness analysis. Figure 4.4 illustrates two cost functions: C_T, cost of the terrestrial system, and C_S, cost of the satellite system: both functions of X capability. It might be the case that, at lower levels of capability (less than X_1), the terrestrial system is more cost effective and, for higher levels, the satellite is clearly more attractive. The cost-effectiveness term, CET, is simply the difference, $C_T - C_S$. When CET >0 the satellite is more attractive, though any improved terrestrial system could provide the same capability when capacity benefits are being considered. In this case, CET is the only benefit the satellite can claim when compared to the improved terrestrial system. If the satellite is compared to the current terrestrial system for the given capabiltiy, X_1, than the benefit is CB + CET.

On the other hand, the terrestrial system is unable to provide capability X_2 and, as a result, has an infinite cost over this interval. If the improved terrestrial systems (with capability X_1) is in place when the satellite is introduced, the satellite can claim only the timeliness benefit, T_B. If the current system is in place when the satellite begins to compete, the entire term, CET + CB + TB, can be claimed. Note that the use of the CET term makes all benefits net benefits. Table 4.2 summarizes the above discussion.

TABLE 4.2 DEFINITION OF NET BENEFITS
SCENARIO 1: SATELLITE VS. CURRENT TERRESTRIAL SYSTEM
$NB_1 = TB + CB + [CTC - SC]$
SCENARIO 2: SATELLITE VS. IMPROVED TERRESTRIAL SYSTEM
$NB_2 = TB + [ITC - SC]$
WHERE: NB_1 ARE THE NET BENEFITS OF SATELLITE-AIDED MOBILE COMMUNICATIONS IF THE CURRENT TERRESTRIAL SYSTEM IS IN PLACE WHEN THE SATELLITE BECOMES OPERATIONAL
NB_2 ARE THE NET BENEFITS OF SATELLITE-AIDED MOBILE COMMUNICATIONS IF THE CURRENT IMPROVED TERRESTRIAL SYSTEM IS IN PLACE WHEN THE SATELLITE BECOMES OPERATIONAL
TB ARE THE BENEFITS DUE TO TIMELY INSTALLATION OF COMMUNICATIONS SYSTEM
CB ARE THE BENEFITS DUE TO INCREASED CHANNEL CAPACITY
CTC ARE THE COSTS OF CURRENT TERRESTRIAL SYSTEM
ITC ARE THE COSTS OF IMPROVED TERRESTRIAL SYSTEM
SC ARE THE COSTS OF SATELLITE-AIDED COMMUNICATIONS SYSTEM

The cost functions, C_T and C_S, are determined as follows. The function $C_T(X)$, evaluted at a given X, can be either the cost of the improved terrestrial system, ITC, or the current terrestrial cost, CTC. As shown in Table 4.3, ITC is a function of transportable terminal costs, MTC; repeater cost, RC; equipment life, L; transportable terminal operating cost, MOC; repeater operating cost, ROC; repeater deployment cost, RDC; and several system parameters, k_1 and k_2. All cost terms in this equation were taken directly from the current costs for equipment (see Section 4.1.2), although the parameters k_1 and k_2 were set to reflect the known peak communications capacity. Proper choice of k_1 and k_2 guaranteed that there would be enough transportable sets to accommodate a six-channel capacity, as opposed to the current one-channel capacity. The maximum number of large fires occurring simultaneously is estimated to be 63 (see Section 4.2.2). The parameter k_2 was calculated by taking an average of the total number of large fires occurring annually over the past several years.

TABLE 4.3 SUMMARY OF COST MODEL

COST TERMS

$$ITC = \frac{k_1(MTC + RC)}{L} + k_1(MOC + ROC) + k_2\ RDC$$

$$CTC = \frac{k_3(3MTC + RC)}{L} + \frac{k_3(3MOC + ROC)}{L} + k_2\ RDC$$

$$SC = \frac{k_1 MTC}{L} + k_1 MOC + (k_2 * N * CPM)$$

NOTATION

k_1	IS THE NUMBER OF EQUIPMENT SETS (EQUAL TO MAXIMUM NUMBER OF LARGE FIRES OCCURRING SIMULTANEOUSLY)
k_2	IS THE TOTAL NUMBER OF LARGE FIRES
k_3	IS THE NUMBER OF LOGISTICS COMMUNICATION UNITS IN BIFC CACHE
MTC	IS THE TRANSPORTABLE TERMINAL COST
MOC	IS THE TRANSPORTABLE TERMINAL OPERATING COST
RC	IS THE REPEATER COST
ROC	IS THE REPEATER OPERATING COST
RDC	IS THE REPEATER DEPLOYMENT COST
CPM	IS THE COST PER CHANNEL MINUTE
N	IS THE NUMBER OF MINUTES PER FIRE
L	IS THE EQUIPMENT LIFE

Calculation of CTC, the cost of the current terrestrial system, was accomplished by using the cost data presented in Section 4.1.2. Note that there are three transportable terminals in each logistics communications unit currently used by BIFC. The constant k_3, equal to 15, is the current number of logistics communications units in the BIFC cache. The satellite-cost term was calculated parametrically, such that both the cost per transportable unit and cost per channel minute (CPM) were varied over a certain range. The transportable units ranged in cost from $\$2 * 10^3$ to $\$50 * 10^3$, while the CPM term varied between \$0.05 and \$5.00.

4.2.1 Calculation of Benefits

The methodology used to compute the benefits from a satellite-aided communication system is explained in this section. Two approaches were considered: simulation and reliance on expert opinion. Under the simulation approach, a forest fire model would be used to determine the possible benefits from the kinds of improved communication offered by the type of satellite system under consideration. Unfortunately, no suitable model was available. The FIRESCOPE simulation model was considered, but was found to be inadequate for the purpose at hand; it could be used only for fires smaller than those considered here, and there was no good way to elicit the benefits of improved communication from the model. Therefore, expert opinion was used.

The study was carried out in two stages. During the first stage, expert opinion was enlisted to determine the possible benefits from satellite-aided communication in two case studies. During the second stage, these benefits were generalized to the country as a whole, using general fire statistics. The main outlines of the study are described in the rest of this section. For a more detailed discussion of the case studies and the results of the generalization procedure, see Sections 4.3 and 4.4.

Stage 1: Case Studies*

The choice of case study fires was made with the help of fire experts according to the following criteria: since improved communications could best be used in large fires, the selection of case study fires was limited to fires of size class F or G.** Regardless of size, large fires fall into two categories. For the first category, the organization of the fire suppression efforts is relatively simple and the role of communications is relatively minor; for the second, the fire fighting organization is extremely complicated and, hence, communication becomes a major problem. In order to encompass a range of possible benefits in the study, two case study fires, one from each category, were analyzed. From the first category, a hypothetical fire located on the Wenatchee National Forest in Washington State

*A complete listing of persons contacted is contained in Appendix D.

**Class F fires burn 1,000-5,000 acres; Class G fires burn more than 5,000 acres.

was examined. From the second category, the Hog Fire which took place in the summer of 1977 in the Klamath National Forest in northern California was studied.

Fire experts familiar with the case study fires were interviewed to determine what the possible benefits could have been if improved communication had been available during these fires. The experts were given an exact description of what the improved communication would entail. They were told that the satellite-aided system would have a seven-duplex-channel capability with the possibility of facsimile transmission; and that the transportable terminals would be located in BIFC fire cache sites* and could be in operation within approximately one-half hour of arrival at the fire site. They were asked to divide the benefits for each case study into the two categories mentioned earlier: timeliness benefits (those benefits due to the quick deployment of the satellite system as compared to the terrestrial system actually used) and capacity benefits (benefits due to the increased capacity of the satellite system). Although most fire experts agree that all the benefits from improved communication would be due to the savings in fire suppression costs, they were also asked specifically if improved communication might have resulted in a reduction in the number of acres or the value of timber burned. The results of the case studies are presented in Section 4.3.

Stage 2: Generalization

The second problem was how to generalize the case study benefits to the country as a whole. This task was limited by the lack of good national data on forest fires. There is only one publication that gives fire statistics for the country as a whole: Wildfire Statistics, published by the Cooperative Fire Protection Staff Group, a branch of the U.S. Forest Service. Unfortunately, this publication does

*From this they could infer how long it would take the terminals to arrive at the fire site.

not contain statistics at the level of detail required by this study. For this reason, the Forest Service statistics on fires on national forest land available in the annual publication, National Forests Fire Report, and statistics from various groups within the Forest Service were used. In many places, these statistics were generalized to the nation as a whole.

In generalizing the case study benefits to the country as a whole, there are two alternative (but not mutually exclusive) methods. The first is to find an uncertainty band within which the nationwide benefit figure is sure to lie. The other is to calculate a likely point value for nationwide benefits.

The Hog Fire and the hypothetical fire were deliberately chosen as case studies, because they are on opposite ends of the spectrum of possible benefits. The Hog Fire was extremely large, involved a large number of men and required a very complicated suppression organization. As a result, the Hog Fire benefits are larger than those for most fires. The hypothetical fire, on the other hand, was relatively small and required few men and a simple suppression organization. Thus, it is possible to calculate an uncertainty band as follows: the minimum possible benefit value is the value calculated on the assumption that all fires are the same as the hypothetical fire; and the maximum possible benefit value is the value calculated on the assumption that all fires are similar to the Hog Fire. The true value of possible benefits should lie somewhere between these two values.

Using the minimum and maximum benefit values yields a wide uncertainty band. Thus, it is useful to establish a most likely benefit value within this range. To do this, the number of fires similar to the Hog Fire and the number of fires similar to the hypothetical fire were estimated. This is a meaningful exercise, since, according to fire experts, all large fires fall into one or the other of these two categories. Some large fires have complicated logistics needs, and hence, high benefits from improved logistics communication, as in the case of the Hog Fire; all other fires are relatively simple and have low benefits, as in the case of the hypothetical fire. In addition to the number of fires in each category, suppression costs for fires in each category were estimated, so that they could be used to generalize the case study results. The results of the generalization procedure are presented in Section 4.4.

4.2.2 Traffic Model

Since fires occur in a seasonal pattern, the number of dedicated channels required throughout the year varies. It was assumed that the number of channels required on any given day would be equal to the maximum number of fires burning on that day multiplied by the seven channels required per large fire. Thus, it was necessary to determine the maximum number of large fires burning on any given day of the year. This was done by assuming that the seasonal pattern of large fires for the whole country was the same as the seasonal pattern of large fires on national forest lands. Data was obtained on the maximum number of fires burning on national forest lands during the years 1973-1976. These numbers were generalized by applying the ratio of the number of large fires for the United States as a whole to the number of large fires on national forest lands and then multiplied by seven to determine the maximum number of channels required nationwide for every day of the year. The results are plotted in Figure 4.5.

4.3 Case Studies

The results of the case studies are given in this section. After a brief description of the general characteristics of each fire and a description of the communications networks used, the potential benefits from improved communication are shown in terms of timeliness benefits (TB) and capacity benefits (CB).

- DECEMBER 1 - MAY 31:

  7 LARGE FIRES MAXIMUM - 49 CHANNELS

- JUNE 1 - NOVEMBER 30

  63 LARGE FIRES MAXIMUM - 441 CHANNELS

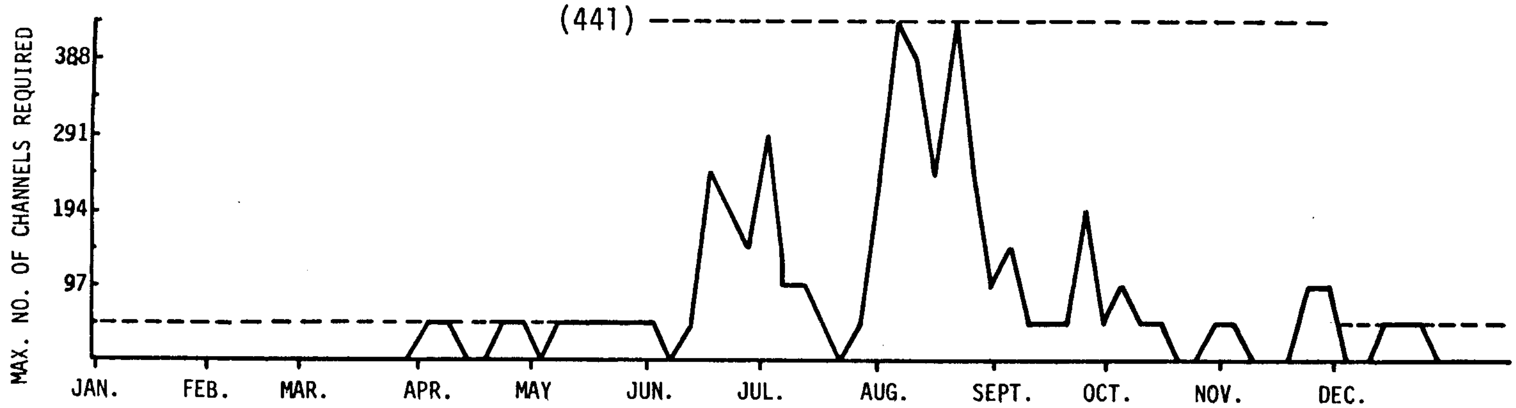


FIGURE 4.5 SEASONAL VARIATIONS IN MAXIMUM NUMBER OF COMMUNICATION CHANNELS REQUIRED

4.3.1 The Hog Fire

Narrative*

The Hog Fire began as 12 separate lightning fires, which eventually burned together. It was discovered by the forest lookout shortly after its origin at 6 p.m. on August 10. Forest personnel from the Salmon River District of the Klamath National Forest began fire suppression efforts immediately, using the regular forest radio network (one voice-grade channel) for both tactical and logistic communications. They also had access to one hot line telephone and one commercial line located in the Sawyer Bar Ranger Station. Only one of these lines was reliable.

At about 10 p.m. that night, a fire camp, initially for ten 20-man crews, was ordered, since it had become apparent that the fire could not be controlled by district personnel. At this point, the Fire Communications Officer began to install the forest service (radio) net, placing repeaters and other equipment. A one-division fire communication system, to be used for tactical communications, was ordered from the regional cache in Redding, California.

Between 1 and 5 a.m. on the following day, August 11, the first fire crews arrived and the service net was in operation. Communications at this time consisted of two duplex radio channels and one phone line, as one of the lines had been burned. It was not until that evening that the radios from Redding arrived and that night they became effective.

Around noon on August 11, it became apparent that the fire would be a long-lasting project fire. A Class I fire team was ordered, and the decision was made to fight the five remaining fires as one. The Class I team, which was being

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*Based on a meeting with George McCluskey, Chief of Firestaff, Bill Cadola and Joe Bowen, Fire Dispatcher, Klamath National Forest, August 17-18, 1978.

demobilized from other fires in the area, arrived that night around 9 p.m. Two more phone lines were ordered for them, but the fire suppression team was told that installation was not possible. The decision was made to set up several fire camps, so three more Class I fire teams were ordered.

On August 12, the third day of the fire, at 2:30 p.m., the National Guard was contacted and requested to bring in its mobile microwave system. The BIFC logistics systems were not available because of the severity of the fire situation throughout the west at that time. It was obvious that the Hog Fire would be prolonged and would involve a large number of men and a very complicated organization. (At this point, there were 600 men on the fire; at the height of the suppression efforts, there were over 5,000 men on the fire.)

The days of August 12 and August 13 were spent planning the installation of the National Guard microwave system, determining the best places to locate it, where to tie into the regular phone system, etc. It was necessary to negotiate with Pacific Telephone and Telegraph Company, as well as several local telephone companies. On August 14 and August 15, National Guard teams set up the system, which involved placing microwave dishes and stringing phone lines to several fire camps. Late on August 15, the system became operational. It provided 12 duplex voice channels (but no facsimile transmission capability) for logistics communication and remained in operation until September 4.*

The fire fighting operations continued to build up until the 12th day of the fire, August 22. They continued at that scale for several days, then began to wind down. Demobilization began around September 1 and continued through the middle of the month.

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*There is no apparent technical reason why facsimile transmission was not used. Facsimile equipment that is compatible with voice grade circuits is available commercially.

Benefit Areas

The fire experts interviewed did not believe that there would have been significant benefits from satellite-aided communications during the first two days of the Hog Fire. During these two days, the fire suppression organization was simple; there were very few men on the fire, and the existing communications were adequate to meet the logistic need.

It was during the next few days of the fire, before the National Guard mobile microwave system was operational, that benefits from satellite-aided communications (seven-duplex-channel capacity, rapid facsimile transmission capability) would have begun to accrue. During these days, a major overordering of men took place, primarily because the logistics communications were poor. The fire boss on the fire ordered a large number of men, but was unaware that it was only possible to obtain these men from Florida, and that it would take several days for them to arrive. The fire experts feel that he would not have asked for the men had he known this at the time, and he would have known this with the earlier logistics communications made possible by the satellite. As a result of this overordering, fire suppression costs were considerably higher than they would have been otherwise. With satellite or other logistic communications during this period, 20 percent of the total expenditure on employment throughout the fire could have been saved. In addition, money could have been saved through lower expenditures on the support facilities required by the additional men: 10 percent of total supplies and equipment expenditure and 2 to 3 percent of travel expenditure could have been saved.

Finally, even after the National Guard system was in place, certain fire suppression costs could have been avoided if rapid facsimile transmission had been possible. (This capability would have been compatible with the 12-channel National

Guard system, but the proper facsimile equipment was not available at the time and so no hard copy was sent over the system.) Experts believe that in addition to the savings just listed, 10 percent of the total expenditure on the fire could have been saved through the increased efficiency of the logistic operation that facsimile transmission capability would have allowed. This 10 percent savings would have increased to 15 percent during the demobilization period.

In addition to the above savings, the National Guard costs of approximately $5,000 per day for the 19 days the system was in operation, together with several thousand dollars in phone bills associated with the system, could have been saved.

The experts interviewed did not believe that satellite-aided, or any other type of logistics communications, could have resulted in any significant reduction in the number of acres burned by the Hog Fire.

Benefit Calculations

The dollar value of the Hog Fire benefits was computed from the cost information available in the daily large-fire reports. From these reports, it was possible to calculate the expenditures for each day in each of several categories: employment, supplies and equipment (including transportation costs), travel, National Guard and the total. Using the benefit percentages given by the local fire experts for each category and the daily large-fire report information, it was possible to compute total benefits due to satellite-aided communications and also to separate these into timeliness and capacity benefits.

One component of the timeliness benefit was the benefit arising from the overordering that took place during the first few days of the fire. This was calculated as:

20% x employment (except for first 2 days)	$1,551,106
10% x supplies and equipment (except for first 2 days)	229,207
2.5% x travel (except for first 2 days)	6,552
Total benefits attributable if no overordering	$1,786,865.

The other component of the timeliness benefit in the Hog Fire was the benefit attributable to increased logistic efficiency during the period before the National Guard system was operational. This was calculated by applying the 10 percent benefit figure to a revised total cost figure for days three through five of the fire. The revised cost figure was what the fire fighting effort would have cost if the overordering had not taken place. The benefits due to efficiency during the days three through five were:

10% x revised cost	$41,335.

Thus, total timeliness benefits for the Hog Fire were: $1,828,200. These timeliness benefits are not based upon the use of facsimile devices.

The capacity benefits, based upon the use of facsimile equipment, in the Hog Fire were the 10 percent savings in total cost during the period after the National Guard system was operational and the 15 percent savings in cost during the demobilization period. These percentages were applied to a revised cost figure that showed what the cost would have been without initial overordering. The benefits were:

10% x revised cost (Days 6-22)	$762,082
15% x revised cost (Days 23-end)	133,839
Total capacity benefits	$895,921.

An additional source of benefits was the potential savings in National Guard costs, which amounted to $72,220.

The total benefits for the Hog Fire were as follows:

Timeliness benefits	$1,828,200
Capacity benefits	895,921
National Guard cost benefits	72,220
Total benefits	$2,796,341.

This amounts to about 24 percent of the total fire suppression costs for the Hog Fire.

4.3.2 The Hypothetical Fire*

The hypothetical fire in the Wenatchee National Forest was chosen because it is as different from the Hog Fire as possible. While it occurs in an equally remote area with little or no access to telephone communications, the logistics problem is much simpler as the fire is on a much smaller scale. A fire lasting from a week to ten days, costing about $500,000 and burning 2,000 acres (a small Class F fire) was considered. The suppression efforts are operated from one fire camp, and the number of men on the fire at any one time is never more than 600. All these aspects make the logistic communications needs of this fire much simpler than those in the Hog Fire.

In the event of such a fire, suppression efforts would begin immediately upon discovery by the district ranger and district personnel. They would have immediate access to two duplex radio channels from the forest net, to be used for both tactical and logistic communications on the fire. As soon as it is determined that the fire would be large, a forest team would be called in, and BIFC communication systems, both tactical and logistic, would be ordered. Because the systems are located in Wenatchee itself and the terrain is well-known, these systems could be operational within eight hours of the beginning of the fire. Satellite-aided communications could not be deployed more quickly than this. Once the BIFC

*Based on interviews held on August 21-22, 1978 with Eugene Moore, Chief Telecommunications Officer and Ed Susich, Fire Dispatcher.

radios arrived, one logistics channel would be available throughout the remainder of the fire, and the fire would be taken off the forest net.

The Chief of Fire Staff in the Wenatchee National Forest estimated the reduction in fire suppression costs that would be possible (with a seven-channel satellite-aided logistic communcation system with rapid facsimile capability) to be between 2 and 3 percent. These savings would be realized through the increased efficiency in the logistic operation allowed by the facsimile capability. None of the savings would be due to the more timely deployment of the satellite system over the terrestrial communication systems. Also, no reduction in acreage burned would be realized through improved logistic communications. Thus, the total benefit of satellite-aided logistic communications in this fire would be:

2 to 3% x total suppression cost = $10,000 to $15,000.

4.4 Generalization of Case Study Benefits

In this section, the generalization procedure described in Section 4.2.2 is used, together with the results of the case studies, to calculate possible benefits from improved logistics communications for the country as a whole. First, an uncertainty band is determined; then a most likely value within the band is calculated.

4.4.1 Range of Possible Benefits

The average suppression costs for large fires occurring on national forest lands in 1976-1977 was $1,278,848 (1977 $). There were 165 large fires nationwide. Therefore, nationwide expenditure on fire suppression was $211,009,986 (i.e., 165 times $1,278,848).

To calculate the minimum benefit value, it was assumed that all large fires were like the hypothetical fire; i.e., that the benefits from satellite-aided communications are 2 to 3 percent of total fire suppression costs, and that all of these benefits result from the increased capacity of the system and not from its timely deployment. Therefore, the minimum benefit value for the United States is $4,220,200 to $6,330,300 per year, all of which are capacity benefits.

Since benefits for the Hog Fire are available by expenditure category, it is necessary to break down the $211,009,986 annual suppression costs for the country. Here it was assumed that the breakdown of national fire suppression expenditure was the same as the breakdown of U.S. Forest Service fire expenditure, as available in the Forest Service (Fighting Forest Fire) FFF Account:

Expenditure Category	FFF Account Percentage	National Expenditure Estimate*
Employment	41.2	$ 86,936,114
Travel	5.1	10,761,509
Transportation, Equipment and Supplies	21.6	45,578,157.

To calculate the maximum benefit value, it was assumed that the benefits in all large fires were equivalent to those in the Hog Fire; i.e., that the benefit percentage for each expenditure category is the same for all large fires as for the Hog Fire. The Hog Fire benefit percentages were applied to the above national expenditure estimates:

Expenditure Category	National Expenditure	Hog Fire Benefit Percentage	Benefit Estimate
Employment	$ 86,936,114	20.0	$17,387,223
Travel	10,761,509	2.4	258,276
Transportation	45,578,157	9.3	4,238,769
Total	211,009,986	8.8	18,568,879
Total Benefits			$40,453,147.

*Where the National Expenditure Estimate equals the product of the FFF Account Percentage and $211,009,986.

Of these benefits, 67 percent are timeliness benefits and 33 percent are capacity benefits,

	Range of Benefits (1977 $)	
	Minimum Value	Maximum Value
Timeliness	0	$27,104,000
Capacity	4,220,000 to 6,330,000	13,349,000*
Total	4,220,000 to 6,330,000	$40,453,000.

4.4.2 Likely Benefit Value

In order to determine the most likely benefit value, it was necessary to divide the country's large fires into two groups: "simple" fires for which benefits were assumed to be similar to those of the hypothetical fire, and "complicated" fires with benefits similar to those of the Hog Fire. Because there were insufficient data to do this directly, use was made of the more detailed national forest statistics. The proportion of large fires on national forest lands over the years 1976-77 in each category was determined as follows. All fires with suppression costs of $1 million or more, as well as all fires burning simultaneously with other large fires, were placed in the "complicated" category; all other fires were put in the simple category. These proportions were then applied to the total number of large fires countrywide, to determine the U.S. yearly average number of large fires in each category.

	No. on National Forest Land 1976-77	% on National Forest Land 1976-77	Yearly No. in U.S.
Complicated Fires	17	33	54
Simple Fires	35	67	111
Total	52	100	165.

*This estimate is based upon the use of facsimile devices as described in the Hog Fire case study.

The likely value for total benefits is the sum of benefits for simple fires and for complicated fires.

Simple Fire Benefits

The average suppression expenditures for simple fires on national forest land in 1976-77 was $401,806. Assuming that average suppression costs are the same throughout the United States, the total U.S. fire expenditure on simple fires is $44,600,000 (= i.e., $401,806 * 111). Applying the hypothetical fire benefit percentage of 2 to 3 percent gives a national benefit for simple fires between $892,000 and $1,338,000; all of this is capacity benefits.

Complicated Fire Benefits

The average fire suppression costs for complicated fires is $2,594,000.* Thus, total U.S. suppression expenditures are $140,098,000. This was broken down into expenditure categories in the same way that total costs were broken down for the maximum benefit value calculation above. The Hog Fire benefit percentages were applied to find the benefits for complicated fires:

Expenditure Category	Yearly Expenditure Estimate	Hog Fire Benefit Percentage	Benefit
Employment	$57,721,000	20	$11,544,000
Travel	7,145,000	2.4	171,000
Transportation, etc.	30,261,000	9.3	2,814,000
Total	$140,098,000	8.8	$12,329,000
Total Benefits			$26,858,000.

Of these benefits, 67 percent ($17,995,000) are timeliness benefits and 33 percent ($8,863,000) are capacity benefits where the capacity benefits are based upon the use of facsimile equipment. The most likely benefit value is $26,858,000 +

*The average value of suppression costs for complicated fires on national forest lands.

$1,115,000 (the average value in the simple fire benefit range) or $27,974,000. Table 4.4 summarizes the benefit calculations.

4.5 Results and Conclusions

Given the calculation of gross benefits found in Section 4.4, net benefits were calculated by accounting for costs of both the terrestrial and satellite-aided communication systems. As discussed in Section 4.2, the costs of both the improved and current terrestrial systems were included and compared to the satellite system costs to see when the satellite became cost effective as a function of terminal costs and satellite connectivity charge per minute for several scenarios.

Scenario 1 assumes that the current terrestrial system is in place when the satellite-aided system is introduced. As a result, the net benefits include both the timeliness and capacity benefits. Scenario 2 assumes that the improved terrestrial system competes with the satellite-aided system and as such only the timeliness

TABLE 4.4 SUMMARY OF GROSS ANNUAL BENEFITS (1977 $000)

	MAXIMUM BENEFIT	MOST LIKELY BENEFIT	MINIMUM BENEFIT
TIMELINESS BENEFITS	$27,104	$17,995	$ 0
CAPACITY BENEFITS	$13,349	$ 9,948	$ 4,220 TO $ 6,330
TOTAL BENEFITS	$40,453	$27,974	$ 4,220 TO $ 6,330

benefits are included. Both scenarios were evaluated under an assumption of a 12- and seven-year equipment life. Figures 4.6 through 4.9 show the final results of the study. Note that, for all figures, both the net benefits and cost-effectiveness terms are presented. Within each cell of the matrices are two boxed numbers. The larger box contains the cost-effectiveness term while the smaller box contains the net benefits.* The heavy line found around a group of cells separate those combinations of transportable terminal and connectivity costs which make the satellite cost effective from those which do not. To the left of the heavy line the satellite is cost effective, i.e., CET > 0; to the right the terrestrial system is cost effective, CET < 0.

Figure 4.6 indicates that under Scenario 1 and for an equipment life of 12 years, the transportable terminal cost must be less than $10,000 and the connectivity cost must be less than $0.15 per minute for the satellite-aided system to be cost effective. Note that all the benefits lie in the $21 to $27 million per annum range. When the satellite-aided system is compared with the improved terrestrial system (see Figure 4.7), the region where the satellite is cost effective is smaller and, in fact, the connectivity charge must be less than $0.10 per minute for the satellite system to be cost effective. Since Scenario 2 includes only the timeliness benefits, the benefits are smaller than Scenario 1 and lie in the $12 to $17 million range.

Figures 4.8 and 4.9 portray similar results but with the assumption of a seven-year equipment life. As may be expected, the reduction in equipment life from 12 to seven years reduced the cost-effective region. Since the equipment cost must be amortized over a shorter period, the total annual cost of both the satellite system and improved terrestrial system increases. Therefore, when the

*The net benefits are the benefits less the cost of the communications system.

CET / NB_1

CONNECTIVITY CHARGE PER MINUTE ($)

COST PER TRANSPORTABLE TERMINAL ($)	.05	.10	.15	.25	1.00	5.00
$2 \cdot 10^3$	115 / 27,000	63.4 / 26,900	11.9 / 26,900	-91.0 / 26,800	-863 / 26,000	-4,980 / 21,900
$3 \cdot 10^3$	110 / 27,000	58.2 / 26,900	6.69 / 26,900	-96.3 / 26,800	-868 / 26,000	-4,990 / 21,900
$5 \cdot 10^3$	99.2 / 27,000	47.7 / 26,900	-3.81 / 26,900	-107 / 26,8000	-879 / 26,000	-5,000 / 21,900
$10 \cdot 10^3$	72.9 / 26,900	21.4 / 26,900	-30.1 / 26,800	-133 / 26,700	-905 / 26,000	-5,020 / 21,800
$50 \cdot 10^3$	-137 / 26,700	-189 / 26,700	-240 / 26,600	-343 / 26,500	-1,120 / 25,700	-5,230 / 21,600

FIGURE 4.6 SCENARIO 1: SUMMARY COST EFFECTIVENESS AND NET BENEFIT ($000) COMPARISON OF SATELLITE COMMUNICATIONS WITH CURRENT TERRESTRIAL SYSTEM FOR 12-YEAR EQUIPMENT LIFE

Econ

CET / NB_2

CONNECTIVITY CHARGE PER MINUTE ($)

COST PER TRANSPORTABLE TERMINAL ($)	.05	.10	.15	.25	1.00	5.00
$2 \cdot 10^3$	67.2 / 17,500	15.7 / 17,500	-35.8 / 17,400	-139 / 17,300	-911 / 16,500	-5,030 / 12,400
$3 \cdot 10^3$	62.0 / 17,500	10.4 / 17,500	-41.0 / 17,400	-144 / 17,300	-916 / 16,500	-5,030 / 12,400
$5 \cdot 10^3$	51.5 / 17,500	.029 / 17,400	-51.5 / 17,400	-154 / 17,300	-927 / 16,500	-5,050 / 12,400
$10 \cdot 10^3$	25.2 / 17,500	-26.3 / 17,400	-77.8 / 17,400	-181 / 17,300	-953 / 16,500	-5,070 / 12,400
$50 \cdot 10^3$	-185 / 17,300	-236 / 17,300	-288 / 17,200	-391 / 17,100	-1,160 / 16,300	-5,280 / 12,200

FIGURE 4.7 SCENARIO 2: SUMMARY COST EFFECTIVENESS AND NET BENEFIT ($000) COMPARISON OF SATELLITE COMMUNICATIONS WITH IMPROVED TERRESTRIAL SYSTEM FOR 12-YEAR EQUIPMENT LIFE

CET	NB_1

CONNECTIVITY CHARGE PER MINUTE ($)

COST PER TRANSPORTABLE TERMINAL ($)	.05	.10	.15	.25	1.00	5.00
$2 \cdot 10^3$	59.70 / 26,900	8.22 / 26,900	-43.30 / 26,800	-146.00 / 26,700	-918.00 / 25,900	-5,040 / 21,800
$3 \cdot 10^3$	50.70 / 26,900	-0.78 / 26,900	-52.30 / 26,800	-155.00 / 26,700	-927.00 / 25,900	-5,050 / 21,800
$5 \cdot 10^3$	32.70 / 26,900	-18.80 / 26,800	-70.30 / 26,800	-173.00 / 26,700	-945.00 / 25,900	-5,060 / 21,800
$10 \cdot 10^3$	-12.30 / 26,800	-63.80 / 26,800	-115.00 / 26,700	-218.00 / 26,600	-990.00 / 25,900	-5,110 / 21,700
$50 \cdot 10^3$	-372 / 26,500	-424 / 26,400	-475 / 26,400	-578 / 26,300	-1,350 / 25,500	-5,470 / 21,400

FIGURE 4.8 SCENARIO 1: SUMMARY COST EFFECTIVENESS AND NET BENEFIT ($000) COMPARISON OF SATELLITE COMMUNICATIONS WITH CURRENT TERRESTRIAL SYSTEM FOR 7-YEAR EQUIPMENT LIFE

CET	NB_2

CONNECTIVITY CHARGE PER MINUTE ($)

COST PER TRANSPORTABLE TERMINAL ($)	.05	.10	.15	.25	1.00	5.00
$2 \cdot 10^3$	107 / 17,600	55.9 / 17,500	4.44 / 17,500	-98.5 / 17,400	-871 / 16,600	-4,990 / 12,500
$3 \cdot 10^3$	98.4 / 17,600	46.9 / 17,500	-4.56 / 17,500	-108 / 17,400	-880 / 16,660	-5,000 / 12,500
$5 \cdot 10^3$	80.4 / 17,500	28.9 / 17,500	-22.6 / 17,400	-126 / 17,300	-898 / 16,660	-5,020 / 12,400
$10 \cdot 10^3$	35.4 / 17,500	-16.1 / 17,400	-67.6 / 17,400	-171 / 17,300	-943 / 16,500	-5,060 / 12,400
$50 \cdot 10^3$	-325 / 17,100	-376 / 17,100	-428 / 17,000	-531 / 16,900	-1,300 / 16,200	-5,360 / 12,100

FIGURE 4.9 SCENARIO 2: SUMMARY COST EFFECTIVENESS AND NET BENEFIT ($000) COMPARISON OF SATELLITE COMMUNICATIONS WITH IMPROVED TERRESTRIAL SYSTEM FOR 7-YEAR EQUIPMENT LIFE

cost of the satellite system is compared to the current terrestrial system, the former is now less cost effective than it was previously, since the current terrestrial system includes fewer terminals.

The main conclusions of this study are as follows:

1. The satellite-aided communication system is cost effective only if the connectivity charge per channel minute is less than $0.15 and the transportable terminal cost is less than $10,000 for any of the studied scenarios

2. The net benefits range between $12 and $27 million per year depending on:

   a. Whether the current or improved terrestrial system is in place when the satellite becomes operational

   b. The cost per channel minute and transportable terminal costs.

It should be noted that the capacity benefits described in this study for complicated fires are based upon the use of facsimile equipment. There is no apparent technological reason why facsimile equipment is not used at the present time, and therefore these capability benefits could also be obtained using current or improved terrestrial systems if channels were to be assigned to facsimile transmission. It is believed that facsimile equipment is not used at present because the limited capacity (i.e., bandwidth or the number of channels) leads to the full use of the existing capacity for command and tactical voice communications. The increased capacity of the satellite system would allow for the assignment of specific channels for facsimile transmission.

5. TRUCKING APPLICATIONS

5.1 Introduction

Trucking firms have been using radio communications for many years as private systems for the interchange of information between the home office and trucks on the road, as well as branch offices, warehouses and maintenance facilities. At the radio frequencies allocated, transmission is line-of-sight, which implies dead spots when the transmission is blocked by manmade structures or the nature of the terrain. The coverage and reliability of communications would be greatly improved by the use of a satellite-aided communication system, in which the transmission path would be directed more nearly vertical to and from a satellite-borne radio relay. The objective of this study was to evalute the cost effectiveness and benefits of a satellite-aided communication system for the trucking industry. The structural elements of the industry, with respect to existing communication systems usage and future communication needs, were examined in order to determine the requirements for specific types of trucking operations and particular classes of trucking firms.

In the following sections, the industry will be described by standard groupings, and those segments of the industry which have the greatest potential for using improved communications will be defined. Discussions of the currently used networks, the utilization of communications capabilities and the rationale for focusing the study on the fleet optimization application also are included.

5.1.1 The Structure of the Motor Carrier Industry

The motor carrier industry is characterized by 25 million vehicles* on the road, covering 266 billion highway miles per year. The industry is complex and is

*American Trucking Association, "American Trucking Trends--1976 Statistical Supplement."

made up of many segments. Certain classes of carriers are regulated by the Motor Carrier Act of 1935, which puts a segment of the freight handlers under Interstate Commerce Commission (ICC) control. They are required to comply with rules on information reporting, tariff schedules and safety issues. Unregulated carriers exist in great numbers, estimated to be about 150,000.*

ICC Regulated Firms

There are 16,506 carriers** under ICC control. These consume 3.7 billion gallons of fuel per year*** and produce $30 billion gross revenues per year.**** Within this group, there are further classifications that describe the diverse nature of the industry. There are private and for-hire carriers, the latter being further broken down into common, contract and local cartage categories. Firms are then divided into groups, by gross revenues, as follows:

Class I:	Greater than $3 million
Class II:	Between $1 million and $3 million
Class III:	Less than $1 million.

As a general rule, Class I and II carriers are large fleets, handling higher revenue types of freight. This leads to 90 percent of the industry's gross revenues being accounted for by the 4,000 firms.

Private fleets, in simplest terms, are those that handle freight of a limited nature; i.e., a manufacturer delivering its own product.

The common carriers may be involved in operations on either regular or irregular routes, spelled out in their operating authority. The former is clearly stated as service between two points, on certain roads and for specified

*Ibid.

**ICC Annual Reports, 1977.

***American Trucking Association, "American Trucking Trends, 1976."

****American Trucking Association, "Financial and Operational Statistics 1977."

commodities. They may be either truckload (TL) or less-than-truckload (LTL) type shipment, for local pickup and delivery (PUD) or over-the-road (OTR) long-distance hauling. LTL, by ICC definition, is a shipment weighing less than 10,000 pounds.

Unregulated carriers, firms which are not subject to ICC rules, qualify by being private (not-for-hire) fleets, and/or operating solely within a commercial zone or between contiguous commercial zones.

Common Carrier

The certificate sought by a prospective common carrier would "entitle and require" him to carry property for any person over the route or in the territory for which he holds that certificate.[*] The burden of proof is on the applicant to show that his creation of a carrier service is required because others providing this service at present are unable to meet the requirements of those who would hire him.

The purpose of this "public convenience and necessity" clause is to strive for a level of service which can be, at the same time, sufficient to handle the demand and such that the industry can expect to derive a profit.[**] The applicant must then show that he is "fit, willing and able" to provide this service.[***] Included as part of his proof must be the availability of equipment, manpower and knowledge of operation to fulfill the existing needs. In addition, he must show an ability to expand to meet future needs.

Contract Carrier

The basic concepts of forming a contract carrier service are again "public convenience and necessity," and a willingness and ability to provide service as previously discussed.

[*] Rabinowitz, Marsha, "Laws and Regulations Affecting Goods Movements," M.S. Thesis, Polytechnic Institute of Brooklyn, 1975.

[**] Ibid.

[***] Ibid.

The requirements for service, however, are not for the general public but rather a specific company or group of companies. That is to say, the contract carrier will not be obliged to accept all requests for his services. His commitment will be solely to that company or companies with whom he has signed a contract.

Over-the-Road (OTR) Trucking

OTR operations imply longer hauls, which generally begin and end at a terminal, due to equipment size or weight regulations in the urban areas. Contents may be either truckload or less-than-truckload, as before, destined for one or more locations. Company policies may vary with respect to driver's hours of service, with some firms requiring the driver to return home every night, while others may dispatch a truck and driver to travel cross-country. Depending on the type of operating authority, the vehicle may travel a prescribed route or any route within a given territory.

Local Cartage

In local PUD operations, packages are first collected for sorting at a terminal facility. They then are redistributed, perhaps having been combined with those brought in by an over-the-road haul, for delivery on a systematic route basis. In general, they are less-than-truckload, requiring a minimum of equipment or manpower assistance.

Service vehicles, such as those used for mail, solid waste or utilities, also operate within a local area. In both cases, there is driver-dispatcher contact periodically throughout the day to direct or redirect routes and stops.

Local cartage operations are by common or contract carriers that typically function within a commercial zone, between contiguous zones, where fleet trucks return to the home base or terminal daily. It is strictly defined as general freight cartage, with 75 percent or more of the business being common cartage meeting previously stated geographic constraints. Until April 1978, this was set at a 50-mile radius of the terminal; however, the zone is now defined by population within an area and may extend to 100 miles.

PUD carriers may be ICC-regulated, either because they do not meet commercial zone requirements, or other segments of the firms' operations dominate their revenues.

Irregular Route Carriers

This group is made up of two main types of goods movers: household goods carriers, such as United Van Lines, and specialized carriers, such as automobile transporters. In each case, an operating authority is designated for a given region and routes may vary, based on the location of shipments. Drivers in 50 to 80 percent of the irregular route carriers are owner-operators, rather than company drivers. The owner-operator may contract to work for a firm for from two months to two years and receives a percentage of the revenue generated by the haul; company-hired drivers are paid at an hourly wage rate, whether they are traveling empty or loaded. The specialized carrier generally requires special equipment, which may not be usable for general hauling purposes.

5.1.2 Review of Appropriate Carrier Groups

The first level of review was financial; it was felt that, typically, Class I and II firms could afford to use an advanced technology. Though the percentage of firms appears small, relative to all carriers, it accounts for most of the gross revenues. These firms constitute, therefore, the significant group.

OTR hauling involves regular and irregular route carriers. Only the latter group might be rerouted once dispatched, thereby gaining a benefit from matching equipment to load. OTR empty-mile problems seem to occur because of natural supply and demand imbalances. Recognizing this, the American Trucking Association has begun a service called CISS, the Computerized Interchange Substitute Service, which is a management tool aimed at matching loads to equipment on a day-to-day basis. It is a cooperative program, used mostly by specialized carriers at present to share loads and reduce empty backhauls.

Within these classes, regular route OTR operations were eliminated from further analysis because (1) they cannot be rerouted once dispatched, (due to ICC regulations which generally define the route that must be taken), (2) they generally leave terminals at full capacity in either weight or volume, and (3) their expected time of arrival is known at the destination, where telephones are readily available in case of some problem. Given these facts, inclusion of this group as part of the potential market could not be justified.

Irregular route carriers tend to be largely owner-operators, so there would be a problem in allocating equipment costs and determining the ability of individual drivers to participate. As with OTR operations, they operate between points where adequate telephone services are provided. Private fleets and unregulated carriers--both OTR and PUD--were not studied due to the unavailability of data. Finally, regulated local cartage carriers were examined as a group. With these it was found that there were data on the cost of elements of the operation, performance information and seemingly a need for improvement over the current communication system. Potential applications that were developed included the safety of driver and cargo, regulatory compliance and fleet optimization. These will be detailed and reviewed in Section 5.1.4.

5.1.3 Existing Terrestrial Networks

Each firm in the industry currently uses a combination of the available technologies, based on management philosophies and the cost effectiveness of acceptable equipment. Telephone service includes standard local and long-distance (toll) calls which, for driver-dispatcher communiques, may be operator-assisted. In some instances, WATS lines have been leased for customer and driver use. They are limited in their coverage, as different regions must be purchased individually; also, each trunk may only accept one call at a time. Tied in with this may be some facsimile equipment to transmit and receive details on shipments. Many truck stops across the country have such equipment available, so drivers can send information ahead to expedite necessary paperwork.

Citizen's band and two-way radios are being used for both intraterminal equipment management and driver-dispatcher communications within the appropriate range. They are currently limited by line-of-sight and weather constraints. With the concern for driver and cargo safety, CB and other two-way radios have also served the purposes of providing conversation to keep drivers alert and sending help in case of breakdowns. Interest is beginning to pick up in improved communications, particularly digital capabilities for data transmission, billing and general recordkeeping.

5.1.4 Review of Applications

Safety

There are three major areas under the safety heading. These are: driver fatigue, driver and cargo safety during breakdown or with respect to potential hijackings and equipment tracking.

In discussions with various trucking-firm executives on OTR operations, there was more concern expressed about cargo safety and breakdown-related problems than about driver fatigue. This is probably due to the tighter regulations of hours of service that limit maximum driving time before a substantial rest is taken. James Boyd, President of the Oil Field Haulers Conference felt that CB chatter helps to keep the drivers awake and alert.

Cargo safety issues led to many indications that tracking and monitoring capabilities were desirable. Kenneth Hauck, Managing Director of the Equipment Interchange Association, Bill Elder, Director of Communications, and Clarke Martin, Assistant Director of Safety, all from the American Trucking Association, mentioned other valuable features a system would need to interest most carriers. They include: monitoring box temperature, oil and tire pressure, gas level and the like; setting up police cooperation when moving heavy or wide loads, and preprogramming a route such that deviation (for instance, in case of a hijacking) would cause the mechanical failure of the carrier.

Several firms were interested in the rapid dispatching of safety crews in case of a breakdown. The experiment between General Electric, Cooper-Jarrett and NASA is primarily directed at this aspect of satellite-aided communications. In addition, Marty Schroeder, Director of Greyhound Bus Line's Communications, indicated that for operations where they are handling freight aboard their passenger vehicles, safety is a crucial issue. They now rely on receiving assistance from passing trucks with CB radios who call for police help. Although it is an important issue, there is little data that would allow for a quantification of the savings with improved communications. The safety area was left for future study.

Regulatory Compliance

Data collection for eventual report generation and use in central billing systems were the main reasons for introducing this application. The link between regulatory compliance and satellite-aided communications seems to be the transmission of data directly from driver to computer, which would then automatically be processed and prepared for reporting. Current policy demands, however, that when required at all, a driver's log be available for public viewing. As such, this would be a duplication of effort and not accomplish any savings. Firms such as St.

Johnsbury have centralized accounting facilities that receive driver input at the end of the day to produce locally-generated invoices by the next morning. For such an application, there are potential savings. Georgia Highway Express has more than 6,000 shipments a day passing through their Atlanta terminal. They expressed interest in an automatic billing system. With respect to reporting steps, accounting procedures now take the driver input and combine it with information from a dispatcher or other involved personnel. The required details then are extracted to be regenerated in whatever form is needed. There are time lags in actually receiving inputs. Often delays occur in processing forms because they are generally handwritten, and sometimes contain illegible words, omissions or errors. A data bank linked to the communication system would allow direct input of necessary items, such as times for pickups and deliveries, delays, paid or unpaid fees, etc. Savings might also be realized in the accuracy of recordkeeping, the output being operated on by the optimization procedure described in the next section.

Computerization of tariffs is a long way off, due to their complex structure. That appears to be the key to achieving benefits in the regulatory compliance area. The application was discussed with each firm and it was decided that, based on the unlikelihood of this coming to fruition in the near term, estimation of savings was virtually impossible; the area was also reserved for later study.

Fleet Optimization

For PUD operators, interaction with a central headquarters office could provide for route and/or schedule changes or increase the number of pickups per vehicle-trip, thereby reducing the number of truck trips. This could also reduce the mileage of each freight vehicle or increase the utilization of manpower and equipment. Although telephone calls can and do provide some link, a more dynamic mechanism would allow communications with unlimited and unconstrained frequency, without planning for stops or spending time attempting to find a telephone or place a call. Further, it would optimize operations over the whole fleet, not just a single vehicle.

Routine intracity operations usually involve deliveries during the morning and pickups for most of the afternoon. Obviously, the morning route is known when the truck is loaded at the terminal; however, most pickup requests are called in during the morning, leaving the driver-dispatcher two options. Either, transmit information using telephone or radio communications or wait until the truck returns to the home terminal. The latter option is, most times, unwarranted and highly inefficient, unless pickups are made simultaneously with deliveries.

In the areas which are effectively covered by radio, drivers may receive instructions while en route, at stop lights or during recordkeeping times. The use of communications tends to minimize the time spent handling such details, particularly when firms require drivers to report in after every stop.

Where such capabilities do not exist, or are less than 100 percent effective due to dead-spot or weather problems, to maintain strict driver control, it would be necessary for drivers to telephone in. The total additional stop time estimated by Bill Bacola, Chief Industrial Engineer with APA Transport of North Bergen, New Jersey, was two minutes for the driver-dispatcher communication without radio. Richard Staley, a Senior Economist with the American Trucking Association, estimates an average of 16 to 18 stops per day per vehicle. These two items imply that half an hour or more of driver time may be spent in telephoning.

The benefits a firm might derive fall into several categories. They might, with the same fleet, be able to handle additional freight. If no increase in volume could be made, they could conceivably reduce the amount of equipment or eliminate duplicate routes. Each of these implies fuel savings.

Current dead-spot problems, availability of data on the operations and the cost of terrestrial systems that offer comparable coverage to proposed satellite-aided systems, led to the decision to focus on the fleet optimization application for the present study. A pictorial diagram of the satellite-aided and current terrestrial communication systems for PUD trucking is found in Figure 5.1.

5.2 Benefit-Cost Model

The theoretical economic framework used for this study is outlined under this heading. The end product of the analysis is the determination of net benefits (benefits net of cost) for a single trucking firm. The five sample firms studied and the generalization are discussed in Sections 5.3 and 5.4 respectively.

The benefits that will accrue to society if a satellite-aided communication system is implemented depend on the nature of the terrestrial system in use when the improved, satellite-aided technology is introduced. That is, the incremental benefits of the satellite system depend on the quality and coverage of the existing terrestrial system. Therefore, benefits are considered for two scenarios:

1. Satellite benefits if an improved coverage terrestrial system is the alternative
2. Satellite benefits if the current (limited coverage) terrestrial system is the alternative.

The improved terrestrial system defined by this report will offer 100 percent coverage of a firm's commercial zone.

For the first scenario, the net benefits, NB^1, to trucking firm i from the use of a satellite-aided system can be expressed as

$$NB_i^1 = ITC_i - SC_i \tag{5.1}$$

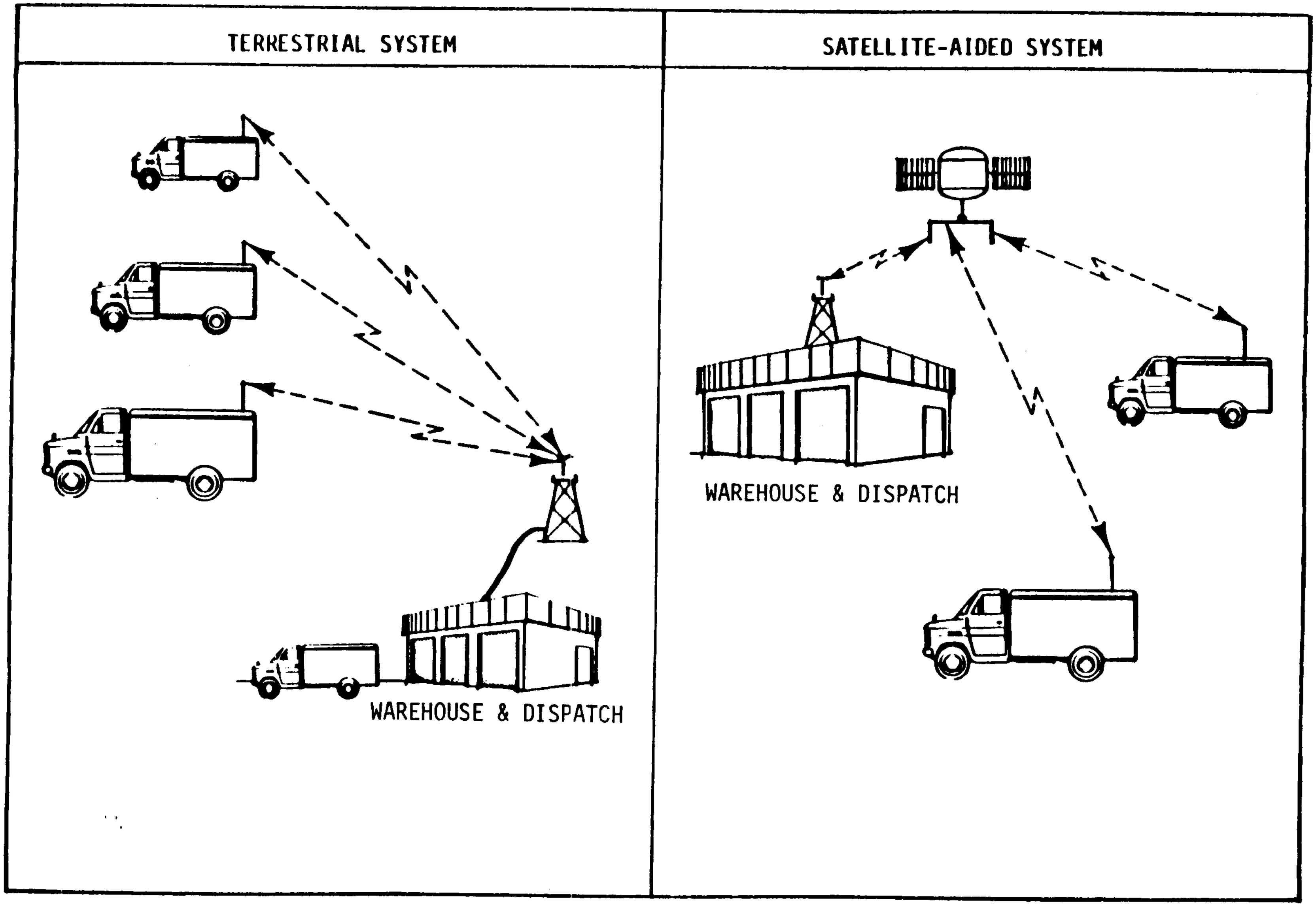

FIGURE 5.1 COMPARISON OF COMMUNICATION SYSTEMS

where ITC and SC are the costs of the improved terrestrial and satellite-aided systems respectively. Therefore, the net benefits are cost-savings benefits. There are no productivity benefits since the improved terrestrial system offers 100 percent coverage.

The improved terrestrial system cost is determined as follows:

$$ITC_i = a_1 \left(\frac{MTC}{L} + MOC \right) + a_2 \left(\frac{BTC}{L} + BOC \right) + a_3 \left(\frac{TCC}{L} + TOC \right) \qquad (5.2)$$

where a_1 is the number of mobile units, a_2 the number of base units, a_3 the number of towers, MTC, BTC and TCC are the mobile unit, base terminal and tower capital costs respectively. L is the asset life time and MOC, BOC and TOC are the annual operating costs of the mobile, base and tower units respectively. The satellite system cost is determined by

$$SC_i = b_1 \left(\frac{MTC}{L} + d \frac{MTC}{L} \right) + b_2 \left(\frac{BTC}{L} + BOC \right) + b_3 \, CPM \qquad (5.3)$$

where b_1 and b_2 are the number of mobile and base units respectively, b_3 is the number of connectivity minutes required by the firm, CPM the cost per channel minute and d is the operating cost as a percentage of capital cost. Equation 5.2 employs a known operating cost, while Equation 5.3 uses a percentage to estimate satellite terminal operating costs, since mobile capital costs are treated parameterically by the analysis (see Section 2).

The net benefits of the second scenario do include productivity benefits, since the existing system has less than 100 percent coverage (see Section 5.1). As a result, use of the satellite system can reduce the number of missed pickups or wasted trips. The second scenario net benefits, NB^2, are given by:

$$NB_i^2 = PB_i + (CTC_i - SC_i) \qquad (5.4)$$

where CTC is the current terrestrial cost, and PB_i is the productivity benefit. With all other variables being defined as before, the current terrestrial cost is given by:

$$CTC_i = c_1 \left(\frac{MTC}{L} + MOC \right) + c_2 \left(\frac{BTC}{L} + BOC \right) + c_3 \left(\frac{TCC}{L} + TOC \right) \tag{5.5}$$

where c_1, c_2 and c_3 are the number of mobile, base units and tower units respectively.

Determination of the productivity benefit for a particular firm is accomplished as follows. The average driver is assumed to make S stops per day. Without radio communication, the driver loses an additional t minutes on average at each stop. The t minutes are spent finding a phone, reporting deliveries and receiving additional instructions from the home office. The average hourly wage of the union pickup and delivery driver, w, is used to measure the value of the time lost. Thus, the productivity benefit (PB_i) to the firm if 100 percent coverage is implemented is simply:

$$PB_i = (S * t * \frac{w}{60} * n)(1 - a) * b \tag{5.6}$$

where n is the number of pickup and delivery drivers employed by firm i, a is the percentage of the commercial zone currently covered by the firm's terrestrial communication system and b is the percentage of drivers equipped with a mobile unit in their trucks.

Several alternative ways of measuring PB_i were examined before the above method was settled on. The following discussion outlines this process. Although the method now described is preferred to the one finally used, lack of data for some of the sample firms precluded its use.

Driver productivity can be measured by:

- Average hourly wage
- Revenues generated per hour
- Number of items handled per hour
- Number of stops per hour
- Another measure of efficiency based on the ratio of actual time required to cover a route to some standardized time to cover the same route.

Though the first four productivity measures would be useful for comparing the productivity of a single driver over the same route, interroute and intercompany comparisons are best served by the last indicated productivity measure. Clearly a driver handling a shipment of oddly-shaped heavy items to only a few locations will have a different dollar productivity than an air freight PUD driver, whose shipments tend to be high valued commodites.

This final productivity measure is expressed as the ratio of actual time required to cover a route to a standard time set specifically for that route. The standard time can be determined by management personnel. Managers, after riding the route several times, can establish allowances for such factors as traffic congestion, type of commodity transported and distances covered. Once the standard time is fixed, a day-to-day efficiency rating can be computed and compared to a set standard.

Given that a relationship exists between the drivers percentage change in efficiency rating and the changes in revenues generated by the driver, a dollar value can be attached to the value of mobile communication. This can be accomplished by comparing the daily percentage efficiency ratings between a driver in an area covered by the existing communication system and another driver in a dead-spot area. If radio communication does lead to improved driver control, one would expect to find a higher efficiency rating for the drivers operating in areas covered by the communications network.

In practice, though, it might be that the management personnel, in evaluating a driver's route to define the standard time, will adjust the standard mph rate upward and perhaps the time allowed for each stop for those drivers operating in dead-spot areas. For example, a driver, when in an area without mobile communication, might be required to phone in after each stop in order to receive new instructions from the dispatcher. The time required to make this phone call would surely increase the allotted time for each stop. As such, it might be the case that a driver operating in a covered area and a driver in a dead-spot area would have the same percentage efficiency rating.

The more precise way to approach the measurement problem is to compute a driver's efficiency as if he were operating in a "covered" area. If the driver's efficiency rating declined under the new standard with shorter stop-time allotments and a higher standard mph requirement, this change in efficiency, or rather its dollar equivalent, would be the benefit derived from mobile communications. Note that, due to the nonlinearity of percentages, the percentage decline is not equal to the percentage increase in efficiency with mobile communications coverage. One would have to compute the percentage change between the old ratio and the new ratio directly.

In conclusion, there are two ways of measuring changes in efficiency using the standard versus actual time technique. If on one hand the stop-time allotments and mph are identical for all drivers, then the proper measurement is the comparison of percentage efficiencies between drivers in covered zones with drivers in dead-spot zones. This is the relevant variable, since changes in actual time due to improved communications are otherwise obscured by route and commodity differences. On the other hand, if the standard mph and stop-time allotments based on traffic and commodity constraints are different for drivers in covered and uncovered areas, then the proper way to proceed is by the method discussed in the previous paragraph. The latter method implicitly assumes that, on the surface, the efficiency rating of a driver would not change when the communication system is introduced in noncovered areas. This is because the management personnel would change the standard allotments with the decrease in actual time.

5.3 Case Studies

Now that the methodology used for computing benefits and costs has been defined, it will be shown how the actual calculations were performed. In general, the costs and benefits for each communications scenario discussed in Section 5.2 were computed for five sample PUD trucking firms. The results of the case studies were generalized to all PUD trucking firms, as discussed in Section 5.4. Selection of the five sample firms was governed by location, gross revenues, extent of mobile communications coverage, operating ratio and willingness of management to cooperate. The reasons behind the use of location and extent of coverage as sampling criteria are obvious. Gross revenues and operating ratio were chosen as criteria to account for the effect of size and efficiency of operations on mobile communications demand. The operating ratio is calculated by dividing operating costs by operating revenue. The ratio is a number less than or equal to 1.00 and typically varies between 0.6 and 0.99. A firm with an operating ratio above 0.9 is considered to be quite efficient and profitable.

5.3.1 The Sample Trucking Firms

The sample firms chosen were:

- APA Transport of North Bergen, New Jersey
- City Freight Lines of Los Angeles, California

- Cooper-Jarret of Morristown, New Jersey
- Georgia Highway Express of Atlanta, Georgia
- St. Johnsbury of Cambridge, Massachusetts.

The nature of each firm's communication system as well as its financial status are described next. The reader is referred to Table 5.1 for a quick summary.

1. <u>APA Transport</u>

APA describes their system as a standard Motorola dispatch system with a 25- to 30-mile range from the dispatch transmitter. APA has had some sort of radio dispatch for 21 years, though most of the current equipment is approximately 12 years old. APA has radio dispatch operations in five locations: North Bergen, New Jersey; Meridian, Connecticut; Canton, Massachusetts; Bethpage, Long Island, New York; and Philadelphia, Pennsylvania. APA trucking has 160 mobile units in the New York metropolitan area; these are served by a tower located on the World Trade Center. The current New York network covers 80 percent of the area, although only 60 to 65 percent of the area is covered all the time, due to changing dead-spot areas. Two more towers are planned: one on Garret Mountain in

TABLE 5.1 SAMPLE TRUCKING FIRMS

REVENUE CLASS ($)	FIRM	OPERATING RATIO AS A PERCENT (1976)	COMMUNICATIONS CHARACTERISTICS		PERCENT OF FLEET WITH MOBILE UNITS
			PERCENT COVERAGE OF COMMERCIAL ZONE	NUMBER OF MOBILE UNITS	
$>75*10^6$	COOPER-JARRET NORTH BERGEN, NJ	98.7	90	700	50
$>50*10^6$	ST. JOHNSBURY CAMBRIDGE, MA	97.6	90	160	70
	APA TRUCKING NORTH BERGEN, NJ	79.5	90	180	80
$>25*10^6$	GEORGIA HIGHWAY ATLANTA, GA	88.2	60	85	40
$> 1*10^6$	CITY FREIGHT LOS ANGELES, CA	91.6	95	30	95

Patterson, New Jersey, and another in Rockland County, New York. The new system is expected to give 90 percent coverage of the New York area.

The remaining terminals each have approximately 40 mobile units, for a systemwide total of 320 mobile units. Each truck communicates 16 to 18 times a day; the average call ranges from 0.5 to 0.8 minutes.

2. City Freight Lines

City Freight Lines has installed a sophisticated mobile communications and data transmission network, which will cover the entire Los Angeles Basin (approximately 22,500 square miles) by 1979. The coverage area extends from Santa Barbara to San Diego in the south and from Los Angeles International Airport to San Bernadino in the east. The system consists of transmitters located at four separate facilities which share two towers, one located on Mt. Verdugo, the other on Mt. Lucan. By 1979, a third tower will be located on Mt. Santiago. The four facilities are located as follows: two in Los Angeles proper, one at Los Angeles International Airport (Atlantic Transfer Trucking)* and one in Carson. The system has a 120-duplex-channel capability; however, only 30 to 40 of these are used for mobile communications (both voice and data) with trucks. The remaining channels are used for fixed point-to-point data and voice communication between warehouses.

The capital costs for this system historically have amounted to $360,000. Tower construction costs averaged $50,000 each; equipment averaged $10,000 per facility site. The 30- to 40-duplex channels devoted to mobile communications carry the traffic generated by approximately 30 trucks (mobile units), though the system could carry much more. There are about 30 data transmissions a day from

*The Atlantic Transfer communications network should be linked with City Freight's network by January 1, 1979.

each mobile unit, each transmission lasting only a few seconds; and about six voice transmissions, each lasting one-half to one minute.*

3. Cooper-Jarrett, Inc.

The Cooper-Jarret mobile communications network covers 40 cities in the Northeast. Each of the warehouses in the 40 cities has its own transmitting antenna and coverage area. Although it was determined that Cooper-Jarret has 700 mobile units systemwide, more information was not forthcoming.**

4. Georgia Highway Express

Georgia Highway Express uses ten-year-old Motorola equipment and two-year-old General Electric equipment. The transmitter has a 20-mile range in the Atlanta metropolitan area and communicates with 80 to 85 mobile units. The truckers call in once an hour and each transmission averages one-half to one minute. The system has only one tower located on top of the warehouse in Atlanta.***

5. St. Johnsbury Trucking Corporation

St. Johnsbury has mobile communications in the Boston, New York and Philadelphia metropolitan areas. It is described as a "typical Motorola system" (but with some General Electric components). St. Johnsbury has 50 mobile units in New York, three years old; 80 mobile units in Boston, seven to eight years old; and 30 new mobile units in Philadelphia. The range of the base stations varies from 25 to 50 miles, although approximately 25 percent of any individual metropolitan area may not be covered due to dead-spot problems. The Philadelphia base station has a range of 50 miles, while the Boston and New York stations have a range from 20 to 25 miles. Transmission in the Boston metropolitan area is from one tower on top

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*Phone conversation with Gregg Owen on November 6, 1978.

**John Murphy, Operations Manager, telephone call, November 6, 1978.

***Forrest Ballard, Chief Dispatcher, telephone call, November 6, 1978.

of the First National Bank of Boston; in New York, from one tower on top of the World Trade Center; and in Philadelphia, from a tower on the Morgan House in the downtown section. The frequency of communication averages 10 to 12 times a day for each mobile unit, with the average call lasting from one to two minutes. The characteristics of the St. Johnsbury mobile communication system are listed in Table 5.2.

It should be noted that the New York operation has two warehouses, one at Maspeth, New York and the other at Kearny, New Jersey, each with its own dispatcher broadcasting at different frequencies but sharing the World Trade Center. A system planned for York, Pennsylvania has not yet been installed.*

5.3.2 Calculation of Benefits for Sample Trucking Firms

This section will describe the method used for calculating productivity benefits (PB_i) for a given firm. The financial and operating data used for these calculations consist of:

1. The Motor Carrier annual reports for 1977, as filed with the Interstate Commerce Commission (ICC). The annual reports consist of various standardized forms that cover such matters as itemized operating expenses and revenue, income statement, employee data and operating statistics. The report is usually filed with the ICC in the March or April following the end of the reporting year. The data used for this study is from calendar year 1977. It should be noted that only Class I and II motor carriers file this report. Class I and II carriers have gross revenues that exceed one million dollars annually.

2. Interviews with officers of the case study trucking firms.

A sample calculation follows for APA Transport of North Bergen, New Jersey. Recall Equation 5.6 in Section 5.2.

$$PB_i = (S * t * \frac{w}{60} * n)(1 - a) * b$$

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*Phone conversation with Hugh Gorely on November 6, 1978.

TABLE 5.2 ST. JOHNSBURY CASE STUDY--CHARACTERISTICS OF COMMUNICATION SYSTEM

COMMUNICATIONS EQUIPMENT DATA FOR ST. JOHNSBURY TRUCKING CORPORATION

FACILITY	TRANSMIT FREQUENCY, Mhz		RECEIVE FREQUENCY, Mhz		POWER ERP WATTS		NUMBER OF UNITS	
	BASE	MOBILE	BASE	MOBILE	BASE	MOBILE	BASE	MOBILE
BOSTON	851.78	806.78	806.78	851.78	NA	NA	1	80
KEARNY	478.58	481.58	481.58	478.58	110	39	2	50
MASPETH	851.13	806.13	806.13	851.13	444	25	NA	NA
PHILA.	452.72 452.67	457.72 457.67	457.72 457.67	452.72 452.67	530	24	1	50

SOURCE: BASED ON A CONVERSATION WITH MR. HUGH GORELY, COMMUNICATIONS CHIEF, ST. JOHNSBURY TRUCKING COMPANY, ST. JOHNSBURY, VERMONT, NOVEMBER 6, 1978.

NA NOT AVAILABLE.

where PB_i is the productivity benefit for the ith sample firm, S is the average number of stops per day, w, the average wage, t, the number of minutes lost at each stop due to lack of communication, n, the number of pickup and delivery drivers, a, the percent of the commercial zone currently covered by the firm's mobile communications network and, b, the percent of drivers with mobile units in their trucks. The values of each variable were determined as follows:

- S was provided by Mr. William Bacola of APA Transport. He stated that each driver makes between 16 and 18 stops per day.
- The value of t was estimated by Mr. Bacola to be two minutes.
- The average hourly wage, w, was calculated directly from the Motor Carrier annual reports. Calculation of the average annual wage ($18,252.28) was done by taking the total wage bill for all pickup and delivery drivers (Schedule 560, column d) and dividing it by the average number of (400) PUD drivers (Schedule 800--Classification of Employees and their compensation). The average hourly wage ($8.71) was determined by dividing the above annual wage by the number of hours worked per year. The number of hours worked per year by the average driver (2094.1) was derived by dividing the total hours (846,052) worked for all PUD drivers (Schedule 800) by the average number of drivers.

- The average number of PUD drivers employed for 1977 is 404 (Schedule 800).
- Both a and b were given by Mr. Bacola (a = 0.90, b = 0.80).

Therefore, the annual benefit to APA of 100 percent mobile communications coverage is $37,392 in 1977 dollars or $40,383 in 1978 dollars.

5.3.3 Calculation of Cost for Sample Trucking Firm

Recall Equations 5.2, 5.3 and 5.5 (in Section 5.2) that describe the general cost model. A sample calculation of Equation 5.5 for St. Johnsbury Trucking is found below. The current terrestrial cost is given by:

$$CTC_i = c_1 \left(\frac{MTC}{L} + MOC \right) + c_2 \left(\frac{BTC}{L} + BOC \right)$$

$$= 180 \left(\frac{1675}{7} + 7.50 \right) + 4 \left(\frac{7085}{7} + 98 \right) + 4\ (1800)$$

where all notation is that defined for the equations in Section 5.2.

The cost data for Equation 5.5 is found in Table 5.3. Since St. Johnsbury rents its tower, the tower capital cost term equals zero (TCC = 0). Note that the base station monthly costs used in Equation 5.5 are net of the rental fee (BOC = 98 percent). The values of the coefficients c_1, c_2 and c_3 are listed in Table 5.2, Section 5.3.1. Unfortunately, only St. Johnsbury was forthcoming with detailed and itemized cost information. Therefore, those unit costs, which are thought to reflect standard Motorola costs, were used for all the trucking firms. Also, the following was assumed:

- Annual operating costs are 3 percent of capital cost
- Equipment lifetime is seven years
- Cellular technology was not considered, since there is an FCC regulation which prohibits use of cellular technology for dispatch applications.

TABLE 5.3 ST. JOHNSBURY CASE STUDY; ESTIMATED COSTS OF COMMUNICATIONS EQUIPMENT

FIXED COSTS		
1) BASE STATION:		
TRANSMITTER		$4,000
ANTENNA		325
DESK SETS @		160
TRANSMISSION LINES		400
INSTALLATION		1,500
MISCELLANEOUS		700
	TOTAL	$7,085
2) MOBILE UNIT:		
EQUIPMENT		$1,600
INSTALLATION		75
	TOTAL	$1,675
MONTHLY COSTS		
1) BASE STATION:		
TRANSMITTER & OTHER MAINT.		$ 44
DESK SET MAINTENANCE @		4
PHONE COMPANY CHARGE FOR TRANSMISSION LINES		50
ANTENNA SITE RENTAL*		150
	TOTAL	$ 248
2) MOBILE UNIT:		
MAINTENANCE		$ 7.50

*ANTENNA SITE RENTAL COSTS RANGE FROM $50 TO $200 PER MONTH.

5.4 Generalization of Case Study Results

The generalization of the case study results was accomplished by (1) classifying the case study trucking firms according to revenue groups, and (2) simply multiplying the benefits of satellite-aided mobile communications to the case study firms by the number of firms in the appropriate revenue group. This method of generalization rests on two critical assumptions. The first is that the sample trucking firms are representative of their revenue group. For example the Georgia Highway express revenue group has 98 firms. The generalization methodology assumes that the average number of mobile units per trucking firm is roughly 85, and that the average communications coverage of the commercial zones is 60 percent. The second major assumption is that the demand for mobile communications scales linearly with the number of firms within the revenue group.

Table 5.4 is a summary of the benefit and cost model used in this study. Note that the total net benefit term, TNB, is simply the weighted sum of the case study net benefits. The individual α_i is the number of firms in revenue group i. Table 5.5 shows both the number of firms in each case study revenue group and the communications traffic.

5.5 Summary and Conclusions

The analysis shows that the net benefits are a function of the terrestrial system that will be in place when the satellite system is introduced. For Scenario 1, the case where the improved terrestrial system is in place before introduction of the satellite, there were no positive net benefits. In the case of Scenario 2, where the current terrestrial capability is in place when the satellite system is introduced, the net benefits are approximately $25 milion per year.

Figure 5.2 shows the net benefits under Scenario 2 over a wide range of mobile unit and connectivity costs. The box in the lower right side of each cell contains the number of sample firms that found the satellite-aided cost effective for their operation. The results show that both the cost-effectiveness and productivity benefits of a satellite-aided system may be quite limited unless the mobile unit and connectivity costs are low.

TABLE 5.4 BENEFIT AND COST MODEL USED IN TRUCKING STUDY

BENEFIT MODEL

SCENARIO 1: APPLICABLE IF IMPROVED TERRESTRIAL SYSTEM IN PLACE WHEN SATELLITE BECOMES OPERATIONAL

$$NB_i^1 = ITC_i - SC_i$$

$$TNB^1 = \sum_{i=1}^{N} \alpha_i \; NB_i^1 \quad \text{for all } NB_i \geq 0$$

SCENARIO 2: APPLICABLE IF CURRENT TERRESTRIAL SYSTEM IN PLACE WHEN SATELLITE BECOMES OPERATIONAL

$$NB_i^2 = PB_i + (CTC_i - SC_i)$$

$$TNB^2 = \sum_{i=1}^{N} \alpha_i \; NB_i^2$$

COST MODEL

CURRENT TERRESTRIAL COST (CTC)

$$CTC_i = c_1 \left(\frac{MTC}{L} + MOC\right) + c_2 \left(\frac{BTC}{L} + BOC\right) + c_3 \left(\frac{TCC}{L} + TOC\right)$$

IMPROVED TERRESTRIAL COST (ITC)

$$ITC_i = a_1 \left(\frac{MTC}{L} + MOC\right) + a_2 \left(\frac{BTC}{L} + BOC\right) + a_3 \left(\frac{TCC}{L} + TOC\right)$$

SATELLITE COST (SC)

$$SC_i = b_1 \left(\frac{MTC}{L} + \frac{d(MTC)}{L}\right) + b_2 \left(\frac{BTC}{L} + BOC\right) + b_3 \; CPM$$

NOTATION

BENEFIT TERMS

NB_i^j = NET BENEFIT OF SAMPLE FIRM i IN SCENARIO j.

PB_i = PRODUCTIVITY BENEFIT OF SAMPLE FIRM i.

TNB^j = TOTAL NET BENEFIT FOR INDUSTRY IN SCENARIO j.

COST TERMS

CTC = CURRENT TERRESTRIAL COST
ITC = IMPROVED TERRESTRIAL COST
SC = SATELLITE COST
MTC = MOBILE TERMINAL COST
BTC = BASE TERMINAL COST
TCC = TOWER CAPITAL COST
MOC = MOBILE OPERATING COST
BOC = BASE OPERATING COST
TOC = TOWER OPERATING COST
CPM = COST PER CHANNEL MINUTE

MISCELLANEOUS

α_i = NUMBER OF FIRMS IN REVENUE CLASS i
N = NUMBER OF SAMPLE FIRMS
a_1, b_1, c_1 = NUMBER OF MOBILE UNITS
a_2, b_2, c_2 = NUMBER OF BASE UNITS
a_3, c_3 = NUMBER OF TOWERS
b_3 = NUMBER OF CONNECTIVITY MINUTES
d = OPERATING COST AS PERCENTAGE OF CAPITAL COST

TABLE 5.5 ESTIMATED COMMUNICATIONS TRAFFIC FOR TRUCKING APPLICATION

REVENUE CLASS ($)	FIRM	NUMBER OF CALLS/MOBILE UNIT/DAY	DURATION OF CALL, MINUTES	NUMBER OF FIRMS IN REVENUE GROUP	NUMBER OF CHANNEL YEARS
$>75*10^6$	COOPER-JARRET	10	1	59	225
$>50*10^6$	ST. JOHNSBURY	10	1	32	31.3
$>25*10^6$	GEORGIA HIGHWAY	8	1	98	43.4
$> 1*10^6$	CITY FREIGHT	30	.5	2032	474.9
TOTAL				2221	774.6

Legend: TOTAL NET BENEFITS (K$/YR) [NO. OF SAMPLE FIRMS WHICH ACHIEVE BENEFITS]

CONNECTIVITY CHARGE PER MINUTE ($)

COST PER MOBILE UNIT ($)	0.05	0.10	0.15	0.25	1.00	5.00
$2 \cdot 10^3$	25,700 [3]	17,100 [2]	15,500 [2]	12,800 [1]	55.6 [1]	0 [0]
$3 \cdot 10^3$	16,600 [2]	15,000 [2]	13,500 [2]	11,600 [1]	0 [0]	0 [0]
$5 \cdot 10^3$	12,400 [2]	11,600 [1]	10,700 [1]	9,110 [1]	0 [0]	0 [0]
$10 \cdot 10^3$	6,240 [1]	5,430 [1]	4,610 [1]	2,980 [1]	0 [0]	0 [0]

FIGURE 5.2 SCENARIO 2: COMPARISON BETWEEN CURRENT TERRESTRIAL SYSTEM AND SATELLITE-AIDED SYSTEM NET BENEFITS

APPENDIX A

SOURCES OF STATISTICAL DATA

1. "Non-Federal Physicians, Hospitals, Population and Income: County Statistics", Physician Distribution and Medical Licensure in the United States, 1975, Center for Health Services Research and Development, AMA, Chicago, 1976, pp. 169-323.

2. "1970 Census Areas of Counties and States", The World Almanac and Book of Facts: 1978, Newpaper Enterprises Association, Inc., New York, 1978, pp. 225-43.

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4. "Percent of Community Hospitals Reporting Emergency Outpatient Units, 1975", Comparative Statistics on Health Facilities and Population: Metropolitan Versus Non-Metropolitan, Division of Information, AHA, Chicago, 1977, p. 51.

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8. Unpublished Data, Trinity Emergency Medical Services Association, Inc., 1976, 1977 and 1978, Fort Worth, Texas.

9. Unpublished Data, Southern Regional Medical Consortium, Southeastern Mississippi Air Ambulance District, 1976, 1977 and 1978, Hattiesburg, Mississippi.

10. Unpublished Data, West Virginia EMS Regions VI and VII, 1977 and 1978, Fairmont, West Virginia.

11. Emergency Medical Services System Development Program (1204-2), Volume I, sponsored by Trinity Emergency Medical Services Association, Inc., 1977, Fort Worth, Texas.

12. Trinity EMS: Executive Summary and Compliance Data, sponsored by Trinity Emergency Services Association, Inc., 1977, Fort Worth, Texas.

13. "Motor Vehicle Traffic Accidents: 1976", Texas Department of Public Safety.

14. "National Estimates of Ambulance Services", National Highway Traffic Safety Administration, Enforcement and Emergency Services Division, U.S. Department of Transportation, January 1978.

APPENDIX B

SELECTED RELEVANT STATISTICAL INFORMATION

TABLE B.1 DEMOGRAPHIC AND MEDICAL DATA FOR U.S. NONMETROPOLITAN AREAS BY STATE

STATE	POPULATION DENSITY (PERSONS/MI^2)	AVERAGE EMERGENCY ROOM DENSITY (THOUSANDS OF MI^2 PER FULL TIME EMERGENCY DEPARTMENT)	POPULATION OF NON-METROPOLITAN AREA
ALABAMA	37.7	4.0	1,366,800
ALASKA	0.3	199.7	131,800
ARIZONA	6.3	17.0	533,100
ARKANSAS	28.1	6.4	1,261,500
CALIFORNIA	16.9	7.6	1,419,400
COLORADO	7.3	11.8	1,032,150
CONNECTICUT	198.7	1.8	360,600
DELAWARE	109.7	1.5	169,400
FLORIDA	38.8	4.6	1,235,200
GEORGIA	42.7	4.0	2,063,100
HAWAII	26.6	5.8	154,900
IDAHO	8.0	13.6	653,300
ILLINOIS	51.8	3.2	2,177,300
INDIANA	79.9	2.6	1,901,200
IOWA	36.2	3.4	1,833,900
KANSAS	17.0	4.8	1,304,300
KENTUCKY	52.1	3.2	1,803,000
LOUISIANA	40.3	4.3	1,410,400
MAINE	25.2	5.9	1,025,100
MARYLAND	102.1	2.9	593,600
MASSACHUSETTS	149.2	1.3	186,600
MICHIGAN	39.2	3.2	1,619,800
MINNESOTA	21.9	4.4	1,454,800
MISSISSIPPI	41.3	4.0	1,801,200
MISSOURI	28.1	5.5	1,709,100
MONTANA	3.9	20.0	548,500
NEBRASKA	11.6	6.8	863,800
NEVADA	1.1	47.8	107,400
NEW HAMPSHIRE	68.6	2.0	558,600
NEW JERSEY	256.6	1.6	477,100
NEW MEXICO	6.4	23.3	743,400
NEW YORK	64.5	2.8	1,986,500
NORTH CAROLINA	73.9	4.8	2,883,700
NORTH DAKOTA	8.3	8.4	563,500
OHIO	88.1	2.6	2,064,600
OKLAHOMA	21.3	5.1	1,201,100
OREGON	10.2	12.4	882,900
PENNSYLVANIA	87.2	2.9	2,281,200
RHODE ISLAND	742.6	--*	85,400
SOUTH CAROLINA	62.3	3.3	1,429,700
SOUTH DAKOTA	7.8	10.7	589,300
TENNESSEE	52.3	3.2	1,656,200
TEXAS	12.5	8.6	2,696,500
UTAH	3.4	35.8	241,300
VERMONT	50.5	3.1	468,200
VIRGINIA	54.0	4.4	1,649,200
WASHINGTON	18.6	7.3	1,899,400
WEST VIRGINIA	54.2	3.0	1,130,100
WISCONSIN	41.2	3.6	1,927,200
WYOMING	3.7	24.3	356,600
TOTAL U.S.	19.9	7.3	58,492,950
CONTINENTAL U.S.	23.0	6.3	58,206,250

*THERE ARE NO FULL TIME ED'S IN RHODE ISLAND.

TABLE B.2 GEOGRAPHIC BREAKDOWN OF U.S. NONMETROPOLITAN AREAS BY STATE

STATE	FLAT AREA (MI^2)	LOW ROLLING AREA (MI^2)	HILLY AREA (MI^2)	MOUNTAINOUS AREA (MI^2)
ALABAMA		18,108	18,108	
ALASKA				389,442
ARIZONA				85,023
ARKANSAS		14,981	14,981	14,981
CALIFORNIA	28,040			56,080
COLORADO		31,518		63,056
CONNECTICUT			1,811	
DELAWARE	1,544			
FLORIDA	31,852			
GEORGIA	16,115	32,231		
HAWAII				5,829
IDAHO				81,634
ILLINOIS	14,004	28,009		
INDIANA	7,935	7,935	7,935	
IOWA		50,620		
KANSAS	25,648	51,297		
KENTUCKY			23,070	11,535
LOUISIANA	17,484	17,484		
MAINE			19,711	9,856
MARYLAND	2,906		2,906	
MASSACHUSETTS		417		834
MICHIGAN	27,553	13,777		
MINNESOTA	33,212	33,212		
MISSISSIPPI	14,551	29,103		
MISSOURI	20,267		40,533	
MONTANA			70,007	70,007
NEBRASKA	24,936	24,936	24,936	
NEVADA				95,649
NEW HAMPSHIRE				8,140
NEW JERSEY	1,220		610	
NEW MEXICO			58,264	58,264
NEW YORK			20,526	10,263
NORTH CAROLINA	13,010	13,010		13,010
NORTH DAKOTA	22,508	22,508	22,508	
OHIO	7,813		15,627	
OKLAHOMA		56,276		
OREGON				86,707
PENNSYLVANIA				26,172
RHODE ISLAND		115		
SOUTH CAROLINA	11,470	11,470		
SOUTH DAKOTA	25,047	25,047	25,047	
TENNESSEE		20,429	20,429	
TEXAS	71,956	71,956	71,956	
UTAH				71,517
VERMONT				9,267
VIRGINIA		10,174	10,174	10,174
WASHINGTON			17,013	34,027
WEST VIRGINIA				20,839
WISCONSIN		31,189	15,594	
WYOMING				97,203

TABLE B.3 U.S. EMS COMMUNICATIONS SYSTEM REQUIREMENTS BY STATE

STATE	NUMBER OF EMERGENCY ROOMS	EXPECTED VEHICLE REQUIREMENT	NUMBER OF EMERGENCY CALLS PER YEAR
ALABAMA	58	210	46,454
ALASKA	13	20	4,450
ARIZONA	33	82	18,112
ARKANSAS	48	195	42,875
CALIFORNIA	72	219	48,244
COLORADO	48	106	23,384
CONNECTICUT	7	56	12,240
DELAWARE	5	26	5,746
FLORIDA	45	190	41,990
GEORGIA	75	318	70,142
HAWAII	9	24	5,223
IDAHO	37	100	22,199
ILLINOIS	84	335	70,018
INDIANA	54	294	64,634
IOWA	97	282	62,322
KANSAS	99	201	44,336
KENTUCKY	69	277	61,302
LOUISIANA	56	216	47,929
MAINE	33	114	25,330
MARYLAND	14	92	20,196
MASSACHUSETTS	6	29	6,324
MICHIGAN	81	249	55,046
MINNESOTA	98	224	49,436
MISSISSIPPI	69	277	61,230
MISSOURI	72	263	58,106
MONTANA	48	84	18,669
NEBRASKA	69	132	29,342
NEVADA	10	16	3,627
NEW HAMPSHIRE	24	86	18,972
NEW JERSEY	6	73	15,198
NEW MEXICO	34	114	25,271
NEW YORK	72	306	67,524
NORTH CAROLINA	87	444	98,022
NORTH DAKOTA	48	87	19,142
OHIO	60	318	70,176
OKLAHOMA	70	185	40,844
OREGON	46	136	29,986
PENNSYLVANIA	57	351	77,544
RHODE ISLAND	2	13	2,890
SOUTH CAROLINA	46	220	48,586
SOUTH DAKOTA	45	90	20,026
TENNESSEE	64	254	56,611
TEXAS	159	414	91,675
UTAH	12	37	8,198
VERMONT	17	72	15,912
VIRGINIA	45	255	56,066
WASHINGTON	42	147	32,259
WEST VIRGINIA	45	174	38,426
WISCONSIN	81	297	65,518
WYOMING	23	122	12,115

SOURCE: "UTILIZATION, PERSONNEL AND FINANCES IN STATES", HOSPITAL STATISTICS: 1976 EDITION, AHA, CHICAGO, 1976, PP. 40-141.

APPENDIX C

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APPENDIX D

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